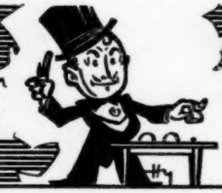
A. W. Engle

Volume 20 NOVEMBER, 1936 Number 11

BULLETIN
of the
American Association *of* Petroleum Geologists

CONTENTS



BULLETIN

of the

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

OFFICE OF PUBLICATION, 608 WRIGHT BUILDING, TULSA, OKLAHOMA

THE BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS is published by the Association on the 15th of each month. Editorial and publication office, 608 Wright Building, Tulsa, Oklahoma, Post Office Box 1852. Cable address, AAPGEOL.

THE SUBSCRIPTION PRICE to non-members of the Association is $15.00 per year (separate numbers $1.50) prepaid to addresses in the United States. For addresses outside the United States, an additional charge of $0.40 is made on each subscription to cover extra wrapping and handling.

British agent: Thomas Murby & Co., 1 Fleet Lane, Ludgate Circus, London, E. C. 4.

German agent: Max Weg, Königstrasse 3, Leipzig, Germany.

CLAIMS FOR NON-RECEIPT of preceding numbers of THE BULLETIN must be sent to the business manager within three months of the date of publication in order to be filled gratis.

BACK NUMBERS OF THE BULLETIN, as available, can be ordered from Association headquarters. Cloth-bound Vol. 2(1918), $4.00; Vol. 3 (1919), $5.00; Vol. 5 (1921), $12.00; Vols. 11 (1927) to 16 (1932), Vol. 18 (1934), Vol. 19 (1935), each $17.00. Other volumes, many separate numbers, and a few nearly complete sets are available. Descriptive price list sent on request. Special prices to members and associates. Discounts to libraries. Detailed *10-Volume Index* (1917–1926), $1.00. *Structure of Typical American Oil Fields*, Vols. I and II (1929), each volume $7.00 ($5.00 to members and associates). *Stratigraphy of Plains of Southern Alberta* (1931), $3.00. *Geology of California* (1933), $5.00. *Problems of Petroleum Geology* (1934), $6.00 ($5.00 to members and associates). *Geology of Natural Gas* (1935), $6.00 ($4.50 to members and associates). *Geology of Tampico Region, Mexico* (1936), $4.50 ($3.50 to members and associates).

THE BULLETIN furnishes thirty-five reprints of major papers. Additional reprints and covers for all or part are furnished at cost. ORDERS FOR REPRINTS should accompany corrected galley proof.

Association Headquarters—608 Wright Building, 115 and 117 West Third Street, Tulsa, Oklahoma.

Communications about the Bulletin, manuscripts, editorial matters, subscriptions, special rates to public and university libraries, publications, membership, change of address, advertising rates, and other Association business should be addressed to

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.

BOX 1852

TULSA, OKLAHOMA

Entered as second-class matter at the Post Office of Tulsa, Oklahoma, and at the Post Office at Menasha, Wisconsin, under the Act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized March 9, 1923.

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.

(Organized at Tulsa, Oklahoma, February 10, 1917, as the Southwestern Association of Petroleum Geologists. Present name adopted, February 16, 1918. Incorporated in Colorado, April 23, 1924. Domesticated in Oklahoma, February 9, 1925.)

OFFICERS FOR THE YEAR ENDING MARCH, 1937

RALPH D. REED, *President*, Los Angeles, California
CARROLL E. DOBBIN, *Vice-President*, Denver, Colorado
CHAS. H. ROW, *Secretary-Treasurer*, San Antonio, Texas
L. C. SNIDER, *Editor*, New York, N. Y.

(The foregoing officers, together with the *Past-President*, A. I. LEVORSEN, Tulsa, Oklahoma, constitute the Executive Committee.)

DISTRICT REPRESENTATIVES

(Representatives' terms expire immediately after annual meetings of the years shown in parentheses)

Amarillo: J. D. Thompson, Jr. (38), Amarillo, Tex.
Appalachian: James G. Montgomery, Jr. (37), Oil City, Pa.
Canada: Theodore A. Link (37), Calgary, Canada
Capital: Arthur A. Baker (38), Washington, D. C.
Dallas: R. E. Rettger (38), Dallas, Tex.
East Oklahoma: Ira H. Cram (37), E. F. Shea (37), C. G. Carlson (38), Tulsa, Okla.
Fort Worth: H. B. Fuqua (37), Fort Worth, Tex.
Great Lakes: Frank W. DeWolf (37), Urbana, Ill.
Houston: Kenneth Dale Owen (37), J. Brian Eby (38), Houston, Tex.
Mexico: William A. Baker (37), Tampico, Mexico
New Mexico: Neil H. Wills (37), Roswell, N. Mex.
New York: R. F. Baker (37), New York, N. Y.
Pacific Coast: Roy M. Barnes (37), Louis N. Waterfall (37), Harold W. Hoots (38), Los Angeles, Calif.
Rocky Mountains: J. Harlan Johnson (37), Golden, Colo.
San Antonio: Thornton Davis (37), San Antonio, Tex.
Shreveport: G. W. Schneider (37), Shreveport, La.
South America: L. W. Henry (37), Maracaibo, Venezuela
So. Permian Basin: Robert L. Cannon (37), San Angelo, Tex.
Tyler: James W. Kisling, Jr. (37), Tyler, Tex.
West Oklahoma: Gerald C. Maddox (37), Oklahoma City, Okla.
Wichita: Clare J. Stafford (37), Wichita, Kan.
Wichita Falls: J. J. Maucini (38), Wichita Falls, Tex.

DIVISION REPRESENTATIVES

Paleontology and Mineralogy
Gayle Scott (37), Fort Worth, Tex.
Maynard P. White (37), Ardmore, Okla.

Geophysics
Gerald H. Westby (37), Tulsa, Okla.

PACIFIC SECTION (Chartered, March, 1925)

CHESTER CASSEL, *President*, The Texas Company, Los Angeles, California
RICHARD G. REESE, *Secretary-Treasurer*, Standard Oil Company, Los Angeles, California
Membership restricted to members of the Association in good standing, residing in Pacific Coast states. Dues: $1.50 per year

SAN ANTONIO SECTION (Chartered, April, 1929)

ADOLPH DOVRE, *President*, 722 Milam Building, San Antonio, Texas
HARRY H. NOWLAN, *Secretary-Treasurer*, 833 Milam Building, San Antonio, Texas
Membership limited to persons eligible to Association membership. Dues: $2.50. Annual meeting in October

MARACAIBO SECTION (Chartered, April, 1930)

JOHN L. KALB, *President*, Lago Petroleum Corporation, Maracaibo, Venezuela
CHESTER A. BAIRD, *Secretary-Treasurer*, Venezuela Gulf Oil Company, Maracaibo, Venezuela

DIVISION OF PALEONTOLOGY AND MINERALOGY
SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

(Organized, March, 1927; affiliated, March, 1928; chartered, technical division, April, 1930

MERLE C. ISRAELSKY, *President*, Houston, Texas
GAYLE SCOTT, *Secretary-Treasurer*, Texas Christian University, Fort Worth, Texas

The Society and the Paleontological Society jointly issue a semi-quarterly, the *Journal of Paleontology*, Raymond C. Moore, University of Kansas, Lawrence, Kansas, and John B. Reeside, Jr., U. S. National Museum, Washington, D. C., editors: subscription, $6.00. Society dues (including subscription to *Journal*), $6.00. A remission of $2.00 is allowed on dues of members or associate members of the Association. The *Journal of Sedimentary Petrology*, W. H. Twenhofel, editor, University of Wisconsin, Madison, Wisconsin, is issued three times a year: subscription, $3.00.

DIVISION OF GEOPHYSICS
SOCIETY OF PETROLEUM GEOPHYSICISTS

(Organized, 1930; affiliated, March, 1932; chartered, technical division, April, 1932)

LUDWIG W. BLAU, *President*, Houston, Texas
JOHN H. WILSON, *Secretary-Treasurer*, 610 Midland Savings Building, Denver, Colorado

The Society issues *Geophysics*, F. M. Kannenstine, editor, 2011 Esperson Building, Houston, Texas: subscription, $6.00; to A.A.P.G. members and associates, $4.00. Society dues (including *Geophysics*), $5.00.

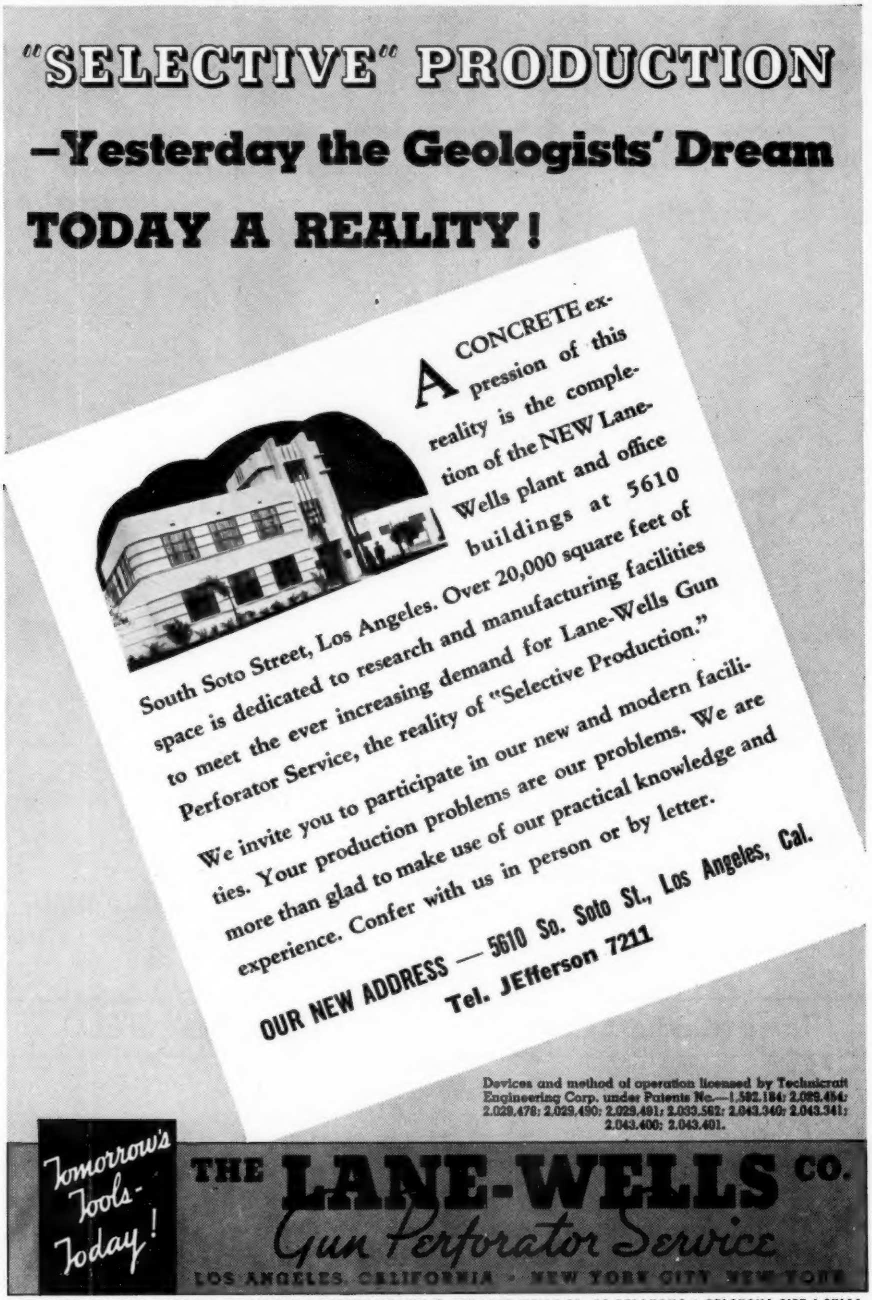
AFFILIATED SOCIETIES

(Dates of affiliation in parentheses)

Alberta Society of Petroleum Geologists, Calgary, Alberta, Can. (31). B. L. Thorne, Secy., 503 Dept. Nat. Resources, Can. Pac. Ry.
Appalachian Geological Society, Charleston, W. Virginia (31). Robert C. Lafferty, Secy., Owens-Libbey-Owens Gas Dept., Box 1375
Ardmore Geological Society, Ardmore, Oklahoma (36). Charles A. Milner, Jr., Secy., 105 C St., S. W.
Dallas Petroleum Geologists, Dallas, Texas (35). R. A. Stehr, Secy., Texas Seaboard Oil Company
East Texas Geological Society, Tyler, Texas (32). George W. Pirtle, Secy., Hudnall and Pirtle
Fort Worth Geological Society, Fort Worth, Texas (31). Paul C. Dean, Secy., 1818 W. T. Waggoner Building
Houston Geological Society, Houston, Texas (32). Wallace C. Thompson, Secy., General Crude Oil Company, Esperson Bldg.
Kansas Geological Society, Wichita, Kansas (31). Harold O. Smedley, Secy., Skelly Oil Company, 510 Ellis Singleton Building
Oklahoma City Geological Society, Oklahoma City, Oklahoma (31). Henry Schweer, Secy., 2810 First National Building
Panhandle Geological Society, Amarillo, Texas (32). G. L. Knight, Secy., Phillips Petroleum Company, Box 665
Shawnee Geological Society, Shawnee, Oklahoma (31). M. C. Roberts, Secy., The Texas Company
Shreveport Geological Society, Shreveport, Louisiana (32). Shapleigh M. Gray, Secy., The Texas Company
Tulsa Geological Society, Tulsa, Oklahoma (31). Larry D. Simmons, Secy., Oklahoma Natural Gas Building


HALOID RECORD
FOR THE TOUGH JOBS


The ANDERSON
PHOTO-RECORD
GO-DEVIL
For measuring Inclination of a drilling well with accuracy, certainty, speed and ease of operation. Run in an Outer Case 1¼-in. or 1½-in. O. D.
4° Disc
10° Disc
26° Disc
With the
NEW
EXPANSIBLE
FINGERS
Dropped in the drill pipe to land on a catcher inserted above the bit, the Anderson Expansible Fingers center and protect the Go-Devil in any size drill pipe during its descent; yet when the Go-Devil enters the drill collar, the spring fingers will center it even though the hole does not exceed 1¾ inches. The fingers are hard-faced and last indefinitely.
INTERCHANGEABLE
INCLINATION UNITS
Inclination is photographically recorded on metal rimmed discs. Units for maximum inclinations of 4°, 10° and 26° are all interchangeable in the same instrument—the records are extremely accurate and easily read.
May we send you our bulletin No. 14
ALEXANDER ANDERSON, INC.
FULLERTON, CALIFORNIA, U. S. A.
LONG BEACH • BAKERSFIELD • SANTA BARBARA
Directional Drilling
Surveyors of Oil Wells Since 1924


"SELECTIVE" PRODUCTION
—Yesterday the Geologists' Dream
TODAY A REALITY!
A CONCRETE expression of this reality is the completion of the NEW Lane-Wells plant and office buildings at 5610 South Soto Street, Los Angeles. Over 20,000 square feet of space is dedicated to research and manufacturing facilities to meet the ever increasing demand for Lane-Wells Gun Perforator Service, the reality of "Selective Production."
We invite you to participate in our new and modern facilities. Your production problems are our problems. We are more than glad to make use of our practical knowledge and experience. Confer with us in person or by letter.
OUR NEW ADDRESS — 5610 So. Soto St., Los Angeles, Cal.
Tel. JEfferson 7211
Devices and method of operation licensed by Technicraft Engineering Corp. under Patents No.—1,582,184; 2,028,454; 2,029,478; 2,029,490; 2,029,491; 2,033,562; 2,043,340; 2,043,341; 2,043,400; 2,043,401.
Tomorrow's Tools-Today!
THE LANE-WELLS CO.
Gun Perforator Service
LOS ANGELES, CALIFORNIA • NEW YORK CITY, NEW YORK
THE LANE WELLS CO. OF TEXAS • HOUSTON & CORPUS CHRISTI • THE LANE-WELLS CO. OF OKLAHOMA • OKLAHOMA CITY & TULSA

For December *Bulletin*

•

Structural Evolution of Southern California

By R. D. REED and J. S. HOLLISTER

•

In addition to publication in full in the December *Bulletin*, "Structural Evolution of Southern California" will also be available in the regular Association binding. This will be a cloth-bound book of approximately 150 pages, 8 half-tone plates, 57 line drawings, 6 tables, and a tectonic map of Southern California in colors, folded loose in a map pocket. The book will sell at $2.00, in heavy mailing carton, postage free, to any address. Extra copies of the colored map (27 x 31 inches) will be available for mailing in a strong tube, post-free, at $0.50 per copy. Orders should be sent to Association headquarters, Box 1852, Tulsa, Oklahoma.

Volume 20 Number 11

BULLETIN
of the
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

NOVEMBER, 1936

DEVELOPMENT OF POROSITY IN LIMESTONES[1]

W. V. HOWARD[2] AND MAX W. DAVID[3]
Tulsa, Oklahoma, and Midland, Texas

ABSTRACT

The continuous porosity possessed by limestone reservoirs is developed mainly by solution by acids resulting from the bacterial decomposition of organic matter and by carbon dioxide formed during these processes.

Porosity is shown to be of three types, namely, equi-solution, channel, and cellular. In the development of these types of porosity, the composition of the rock and arrangement of mineral grains is important.

Reactions taking place within the reservoir, both prior and subsequent to the entrance of oil, may result in the formation of much secondary calcite. The effect of this material upon the results of acid treatment and also that of the insoluble residues released are touched upon briefly.

INTRODUCTION

Most limestone oil reservoirs owe their porosity to solution performed by meteoric waters, yet little has been published on the mechanics of this process. This investigation on the development of porosity in limestones was carried on by experimental methods, namely, etching and staining. It is hoped that this work may have practical application, not only with reference to the origin of limestone reservoirs, but also to the variable effect of acid treatment of reservoirs.

The limestones and dolomites used in this report were taken, for the most part, by A. N. Murray from outcrops in Illinois, Indiana, Ohio, and Ontario, during the field season of 1927.

[1] This paper is based on a thesis submitted by Max W. David in partial fulfillment of the requirements for the degree of Master of Science in Geology, in the Graduate School of the University of Illinois. Manuscript received, July 27, 1936.

[2] J. G. Wray and Company.

[3] Sinclair-Prairie Oil Company.

NATURE OF POROSITY IN LIMESTONES

The one thing which seems certain about the porosity of limestones is that it is modified continuously so long as aqueous solutions are present in the rock, that is, so long as it has any porosity. If the solution is at rest, there will be continuous solution and precipitation of carbonates with the development of larger crystals. Although this process will not increase or decrease porosity, it may bring about changes in permeability. If the solution is circulating, recrystallization, solution, or precipitation of introduced materials will take place either individually or collectively.

Thus, one may refer to the present porosity of a limestone as opposed to the former porosity. The former porosity may in turn consist of original and secondary porosity. There may even be several different stages of former porosity corresponding with changes in conditions affecting the rock. In many places, the rock itself contains indisputable evidence of some of these stages.

Continuous and discontinuous porosity.—Murray[4] states that porosity may be divided into two classes: continuous porosity, suited to the accumulation and commercial production of oil, and discontinuous porosity, unfavorable to the accumulation and production of oil. The continuous type may be made discontinuous by the deposition of secondary minerals at strategic points throughout the reservoir. If they are deposited before oil or source material is introduced, it is naturally impossible for certain parts of the limestone to become a reservoir. Murray found secondary calcite crystals which contained globules of oil in limestone at Monon, Indiana. This dates the calcite deposition to both (a) simultaneous growth with the introduction of oil and (b) subsequent growth after accumulation of oil. If deposition of secondary calcite or other secondary minerals throughout a limestone takes place after accumulation of oil, the oil may be locked up in disconnected channels and cavities. The natural recovery of oil from such a reservoir is limited to the connected area surrounding each well.

Limestone reservoirs.—Howard's[5] original classification of limestone reservoirs may be considered as too complex. Actually, the types of limestone reservoirs now known fall into the following classes.

[4] A. N. Murray, "Limestone Oil Reservoirs of the Northeastern United States and of Ontario, Canada," *Econ. Geol.*, Vol. 25 (1930), pp. 452–59.

[5] W. V. Howard, "A Classification of Limestone Reservoirs," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12 (1928), pp. 1153–61.

1. Limestones with secondary porosity associated with former erosion surfaces
   a. Strongly jointed
   b. Not strongly jointed
2. Jointed limestones without secondary porosity

He estimates that 95 per cent of the known limestone oil reservoirs owe their porosity to exposure to weathering. Thus, most limestone reservoirs owe their porosity to solution performed by meteoric waters.

SOLUTION OF LIMESTONES

Meteoric waters.—Although pure water dissolves practically no calcium carbonate, it is important in the development of secondary porosity by solution, in that it carries solvents, such as carbonic acid and organic acids.

There is considerable evidence for the passage of water through limestones. Many joints not normally wide have been observed to be 1–3 inches across. Limestone caverns usually carry considerable water, particularly through the joints. This can be readily seen by observing the ceiling of a wet cave. The intersection points of the joint pattern usually carry the most water; in fact, stalactites usually develop at these points. Also, many joints and fractures are filled with secondary minerals of the types that are deposited from aqueous solutions only.

Carbonic acid.—Because of its abundance, carbonic acid has been considered the most important solvent found in meteoric wateıs. Common sources of carbonic acid are carbon dioxide gas derived from the respiration of plant roots, the decomposition of organic matter, and the washing of the atmosphere by rain. The annual amount produced will vary in different regions, but it must be a tremendous amount in tropical and temperate regions.

In order to dissolve calcium carbonate from limestone rocks, there must be a circulation sufficiently rapid to remove the calcium bicarbonate as it is formed and to bring fresh carbonic acid into contact with the rock.

By the time the waters have reached the ground-water table, if the pathways are by indirect routes, most of the carbonic acid will have been spent. However, if the passages are direct and movement is rapid, carbonic acid may get down to the ground-water zone. If the ground water is not saturated with carbonates and still contains solvents, such as carbonic acid, solution may be expected in the upper part of the zone, as the water moves laterally to some surface drainage system. Water below the water table is generally alkaline, and there is a normal tendency for calcium carbonate to be precipitated in the zone of lateral flow.

Organic acids.—A study of the action of organic acids upon limestones has been made by Murray and Love;[6] consequently only a summarization of their work is given. They conclude:

1. Soil bacteria possess the ability to generate acids which are capable of dissolving calcium carbonate.
2. Carbon dioxide is generated in large quantities as a result of bacterial decomposition of plant material and also as a result of the reaction between the acids generated and calcium carbonate.
3. The bacteria become dormant when the solutions are made alkaline.
4. The time involved in the bacterial decomposition of plants is sufficient to allow the percolation of solutions containing bacteria to considerable depths before toxic conditions are set up.

Other conclusions arising from their study are:

5. The amount of organic acid carried into limestones can not be measured directly.
6. The solvent action of acids generated by bacteria is probably responsible for much if not most of the solution of limestone taking place in nature, as bacterial action, through formation of organic acids, must be much more effective in making limestones porous than atmospheric carbon dioxide.
7. The solvent action of carbonic acid and organic acids resulting from bacterial action is rendered effective by the intimate spatial relationship between the solvents as they are generated and the rocks which these solvents attack.

EXPERIMENT ON AMOUNT OF SOLUTION PERFORMED BY CARBONIC AND ORGANIC ACIDS ON LIMESTONES

The experiments described by Murray and Love were expanded by the writers in order to determine the relative effect of the following reagents on limestone: (1) acids developed as a result of the bacterial decomposition of plant material; (2) carbonic acid as a result of this reaction; and (3) carbon dioxide (carbonic acid) liberated as a result of the reactions between the acids and limestones.

Description of apparatus.—Elm and maple leaves were placed with water and soil bacteria in flasks. The gases developed in the flasks were allowed to pass upward through a cylinder which contained six limestone samples of known weight and porosity. The samples were separated by glass beads and covered by a constant supply of distilled water. The acid developed in the flasks was tested for normality periodically, drained off, and poured into a second cylinder, which contained in the same order corresponding samples of the limestones in the first. This cylinder was connected by tubing with

[6] A. N. Murray and W. W. Love, "Action of Organic Acids upon Limestones," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13 (1929), pp. 1667–75.

TABLE I

RESULTS OF EXPERIMENT SHOWING ACTION OF ACIDS ON LIMESTONE

	Composition Percentage Volume			*Tube A (CO_2 from Leaves)*					*Tube B (CO_2 from Tube C)*					*Tube C (Acid from Flasks)*				
Number	Calcite	Dolomite	Insoluble	Original Weight in Grams	New Weight	Decrease (Grams)	Original Percentage Porosity	Final Percentage Porosity	Original Weight in Grams	New Weight	Decrease (Grams)	Original Percentage Porosity	Final Percentage Porosity	Original Weight in Grams	New Weight	Decrease (Grams)	Original Percentage Porosity	Final Percentage Porosity
1	34	50	16	137.3	137.1	.2	1.0	1.15	95.2	95.0	.2	2.4	2.6	88.5	87.9	.6	4.2	4.9
2	32	7	61	135.3	135.2	.1	1.2	1.3	143.8	143.7	.1	1.2	1.3	133.1	132.1	1.0	1.2	1.95
3	71	20	9	132.8	131.8	1.0	6.7	7.45	109.4	108.7	.7	7.9	8.5	116.0	115.2	.8	8.1	8.8
4	58	32	10	95.0	94.8	.2	1.5	1.7	101.3	100.9	.4	1.3	1.7	116.7	114.5	2.2	.8	2.7
5	70	8	22	201.5	201.3	.2	1.6	1.7	140.9	140.0	.9	2.0	2.6	132.8	131.7	1.1	1.2	2.0
6				147.4	147.0	.4	1.2	1.5	103.4	103.1	.3	1.3	1.6	101.5	100.4	1.1	1.6	2.7

a third so that the carbon dioxide developed by the reaction of the organic acids on limestone samples could pass through. The third cylinder also contained corresponding limestone samples of known weight and porosity.

A gradual increase in the normality of the acids was noted with time. No peak in the strength was noted in either flask, as was observed by Murray and Love.

The evolution of carbon dioxide gas from the flasks was great during the first 2 months of the experiment, which ran for a total of 11 months. A gradual decrease was noted thereafter. No chemical analyses of the acid or gas were made, but the acids smelled like butyric and propionic.[7] Most of the gas was definitely carbon dioxide.

Effect of acids and gas on limestones.—The limestones in the second cylinder were naturally dissolved the most (Table I). Decreases in weight of the samples ranged from 0.6 to 2.2 grams.

The limestones in the third cylinder were dissolved by the carbonic acid derived from the carbon dioxide, which was given off by the reaction between the organic acid and the limestones in the second. Though the decreases in weight of the samples in this cylinder were not so striking as in the cylinder containing the acid, they were nevertheless substantial. Decreases ranged from 0.1 to 0.9 gram.

Samples in the first cylinder lost weight at about the same rate as those in the third. The decreases ranged from 0.1 to 1.0 gram. The greatest decrease in weight in this cylinder was registered by sample 3, a very porous specimen.

The advisability of considering loss of weight as increase in porosity may be questioned, since most of the solution probably took place on the outside of the samples. However, if solution took place in a limestone in place, it certainly would be considered an increase in porosity. Interpreted in terms of porosity, this experiment shows that the porosity of a limestone can be appreciably increased by solution performed by carbonic and organic acids over relatively short periods of time.

There is no close correlation between the amount of solution developed in the different limestone and the calcite contents. However, none of these samples was notably low in calcite, so that in all cases there was an abundance of easily soluble material available.

Conclusions.—The theoretical conclusions of Murray and Love are thus checked experimentally and the effect of organic acids may be considered to be of the order of 1 to 10 times that of carbonic acid.

[7] Acids formed in the same way were found by Murray to be largely butyric and propionic acids, personal communication.

SOLUBILITY OF CARBONATE MINERALS

The order of solubility of certain naturally occurring carbonates in acid solution is as follows: (1) aragonite, (2) calcite, (3) dolomite, and (4) magnesite. In the case of calcite and dolomite mixtures where the grains are uniform in size, approximately 24 parts of calcite are dissolved for each part of dolomite until all of the calcite has gone into solution.

FIG. 1.—Core showing differential solution of calcite-bearing dolomite.

In the case of rocks, this ratio may be modified by the relative sizes of the crystals present and by the mode of aggregation of the carbonates. When both calcite and dolomite are present on an exposed surface, the dolomite is affected to a negligible extent, while the calcite is strongly attacked. Cores possessing old channels filled with pure secondary calcite crystals exhibit this selective feature very well. While being etched with acid, bubbles of carbon dioxide gas distinctly emerge from the openings, but there is practically no

effervescence on the surface of the core; in fact, no appreciable decrease in diameter can be measured after etching in some cases. Figure 1 displays a core in which nodules of calcite have been dissolved very deeply, while the dolomitic part shows minor solution.

Hogbom[8] shows that stalactites from caves in the coral rocks of Bermuda contain only 0.18–0.68 per cent of magnesium carbonate, while the rock from which the waters secured the carbonate minerals are five times as rich in dolomite as calcite. The lime salt was dissolved much more freely than the magnesium compound.

Work by Bischoff, Hunt, Hardman, and Murray and Love points to the fact that calcite dissolves out of rocks much more easily than dolomite, regardless of the solvent.

DEVELOPMENT OF POROSITY IN LIMESTONES BY SOLUTION

The three factors, inherent in the rock, affecting solution to the greatest extent are: (1) the presence of joints and fractures, (2) the nature and frequency of bedding planes, and (3) the nature and arrangement of the grains of the minerals comprising the rock.

Of these, the first can not be studied directly in the laboratory, but the others may be evaluated after treatment of specimens. Most limestones do not give very satisfactory results when studied under the microscope and many large specimens give an illusion of uniformity of texture and composition which is dispelled by etching and staining.

For a study of the development of porosity, rather deep etching with hydrochloric acid was found to give excellent results, and the effects due to variation in composition were accentuated by staining the specimens with potassium ferri-cyanide. As was pointed out by Steidtmann,[9] this reagent stains dolomite blue, leaving calcite white. This, of course, presupposes the presence of some ferrous carbonate in dolomite. The writers found that the method worked excellently, although there were some variations in the blue color, indicating the possibility that its use might not be universally applicable.

Fractures and joints.—Fractures and joints offer the best pathways for meteoric waters to descend to the water table in limestone. In limestones in which there is no interruption in the continuity of the joints to the water table, little more than enlargement or widening of the joints can be expected. To develop secondary porosity by

[8] F. W. Clarke, "The Data of Geochemistry," *U.S. Geol. Survey Bull.* 770 (1924), p. 574.

[9] Edward Steidtmann, "Origin of Dolomite as Disclosed by Stains and Other Methods," *Bull. Geol. Soc. America*, Vol. 28 (1917), pp. 153-54 (abstract).

solution above the water table, it is believed that the flow of water to the water table must be interrupted, so that other outlets may be formed. Several factors, such as close spacing of joints, or large volume of circulating water, may lead to the development of zones of continuous porosity or even cavernous conditions along some beds. The new outlets may also be porous zones parallel with the bedding planes, or they may be calcite-rich zones, where solution will be rapid and penetrative. The presence of water in zones or horizons above the true ground-water table indicates the presence of a type of perched water table in which the underlying barrier is not necessarily entirely impermeable. The outlets may emerge at the surface as springs, or if the bedding is not horizontal, porous or even cavernous zones may be developed downdip, until the formation dips into the water table.

The amount of solution that will take place in the zone or zones selected depends on the bedding in the limestone, the amount of water available, the amount of carbonate it can dissolve, present porosity, and the arrangement and composition of the mineral grains. A very important influence on the nature and number of porous zones that may develop is the oscillation of the water table as a result of structural or climatic changes and length of time during which the water table remains at any one position.

Weller[10] suggests that the development of different cave levels in Edmonson County, Kentucky, may be caused by changes in the levels of the water tables. He also suggests a correlation between cave levels and corresponding river terraces.

Conclusions.—

1. Fractures and joints offer the best pathways for meteoric waters to reach the ground-water table.
2. Joints are usually best developed in the upper part of a rock section.
3. If joints are continuous to the water table, little more than widening of the cracks can be expected.
4. Interruptions in the continuity of the joints allows solution to take place in porous and calcite-rich zones above the water table in addition to the normal widening.
5. Well developed joints in the upper part of the formation may cause rich calcitic zones to be passed without increasing their porosity.

Bedding planes.—One of the important factors that control the development of vertical and lateral solution is the presence of in-

[10] J. M. Weller, "Geology of Edmonson County, Kentucky," *Kentucky Geol. Survey* (1927).

soluble bedding planes in limestones. The nature of the bedding planes varies considerably. Some are just indistinct, straight, or wavy, narrow lines; others are thick, vari-colored clay and shale partings. Several samples after etching and staining revealed that some of the bedding planes were largely dolomite. Figure 2 shows an etched core of this type, in which dolomite is interbedded with the calcite. It suggests that periods of calcite and dolomite deposition took place more or less intermittently.

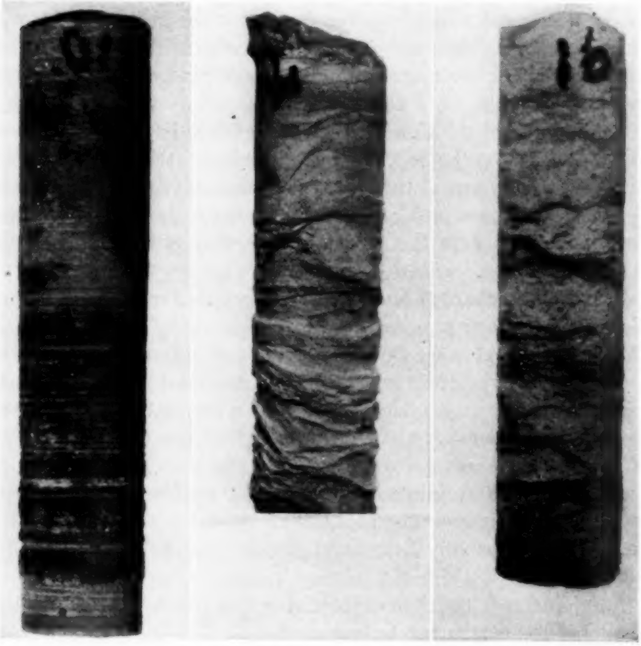


FIG. 2.—Cores showing effect of bedding planes on solubility of dolomitic limestones.

The bedding planes in the cores that were etched plainly showed their confining or controlling effect on the solution. The solution was greatest in the areas of dolomite and calcite in between insoluble bands. The extent to which the smaller or thin insoluble bedding planes affect solution in a limestone can only be inferred. The thicker and more impermeable or insoluble a parting is, the less likely it is for vertical solution to develop and connect higher and lower stratigraphic units. The presence of impermeable or less soluble bedding

planes is probably one of the instrumental causes for the development of porous zones parallel with the bedding.

Arrangement and composition of mineral grains.—If the more soluble minerals, such as calcite, are arranged in a limestone so that they are connected or touching, solution can develop to the extent of these connections. However, if grains of dolomite separate chains or

Fig. 3.—Photomicrograph showing alternating calcitic (white) and dolomitic (dark) bands. Magnification, 20 diameters.

sets of calcite grains, the possibility of developing a continuous channel is greatly reduced. Non-carbonate minerals, such as shale or clay particles are even more effective than dolomite in preventing the development of continuous solution channels.

After etching some limestones, it was found that the insoluble

residue which collected in the bottom of the beakers often contained some dolomite. These dolomite grains apparently had been completely surrounded by calcite grains. As the calcite grains were dissolved, dolomite grains were released and were not entirely dissolved. Figure 3 shows rather faintly the presence of individual dolomite grains in the rich calcite band.

A microscopic examination of solution cavities after etching, usually reveals many projecting dolomite grains. Apparently, such grains have retained a connection either to a calcite grain which has not been reached by the acid, or to a dolomite grain which was not dissolved.

A limestone possessing heterogeneous carbonate minerals is apt to develop the most penetrative or continuous type of secondary porosity by solution, provided that (a) the more soluble carbonate grains are touching and form continuous chains for some distance, (b) there is enough of the more soluble mineral present to permit an appreciable amount of solution, (c) insoluble mineral grains do not prevent the acidic waters from reaching carbonate grains, and (d) there is sufficient relatively insoluble material present to form a rigid though porous mass on removal of the more soluble material.

ORIGINAL AND PRESENT POROSITY

The primary porosity of a limestone is the percentage of pore space present at or soon after deposition. However, few limestones retain their original porosity.

Chalks, coquinas, and many oölitic limestones have high porosity, and many have continuous porosity to some extent. These limestones may be considered immature and represent early stages of induration. Usually, the porosity of coquinas and other fragmental varieties of carbonate rocks is materially reduced by the infiltration of calcite paste or other minerals into the voids. Probably many old very fossiliferous limestones were originally coquinas.

During induration, the porosity of a limestone is made discontinuous. The extent to which the original porosity is retained may be quite difficult to determine, consequently errors are likely to be made. The terms "original" or "primary" and "secondary" should, therefore, be abandoned in favor of "continuous" and "discontinuous" with definite understanding that "continuous" porosity is almost entirely restricted to immature limestones, which are rarely if ever oil reservoirs, or to limestones with secondary porosity, which are frequently oil reservoirs.

As has been already pointed out, mature limestones, that have

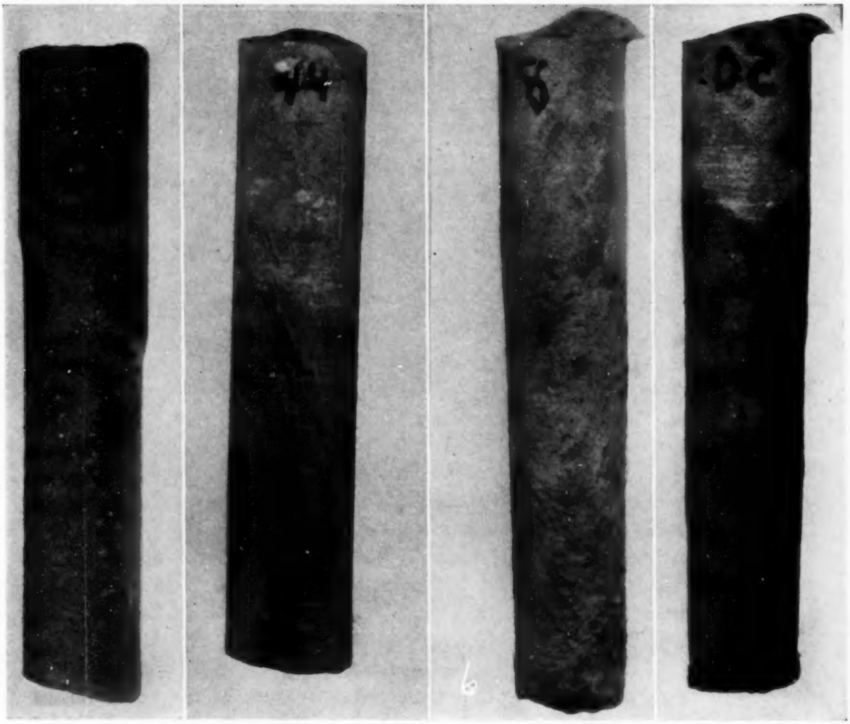


FIG. 4 FIG. 5 FIG. 6

FIG. 4.—Core showing uniform solution of nearly pure dolomitic limestone.
FIG. 5.—Core showing inhibiting effect of uniformly distributed insoluble material.
FIG. 6.—Cores showing irregularities on equi-solution surface.

not been made porous by solution, possess a discontinuous type of porosity. The voids or cavities are factors in the development of secondary porosity by solution, in that they act as "junctions" for the waters that reach them. The junctions will be surrounded by many carbonate mineral grains, some of which may be calcite. If acidic waters can reach these "junctions," solution will start by the way of the calcite route. All of the cavities may never be reached by solution; consequently, not all of them become a part of the continuous porosity system. If petroliferous material is introduced into the limestone by way of the continuous porosity system, it will not reach cavities that are not a part of this system. Utterback[11] has done considerable work on asphalt-bearing limestones and has found that in the specimens in which the asphalt was definitely not indigenous, cavities containing no asphalt were not a part of the continuous porosity system.

NATURE OF SOLUTION AND TYPES OF PATTERNS

The nature of the solution pattern developed depends on the extent to which the factors that govern the development of continuous porosity are present. The present porosity and the arrangement and composition of the carbonate minerals appear to be the most important factors.

The solution patterns fall into rather distinctive groups, for which the following names are proposed: (a) equi-solution, (b) channel, and (c) cellular.

These names are suggestive descriptions of the solution pattern that is likely to develop in a limestone. In addition to these main types, there are combinations which may be developed in certain limestones. These patterns were obtained in the laboratory as a result of etching many "mature" limestone cores.

Equi-solution type.—The characteristic feature of the equi-solution type of limestones is the evenness with which solution takes place. Either (a) the limestone is pure, or composed of a single carbonate (Fig. 4), or (b) the limestone is impure and the arrangement of the non-carbonate constituents is such that it inhibits solution (Fig. 5).

The arrangement of the minerals is ordinarily so even in rocks possessing an equi-solution pattern, that when the rocks are weathered the solution takes place with the same evenness. Thus, fractures and joints are widened by solution and a fracture or fissure type of potential reservoir is developed.

[11] D. D. Utterback, personal communication.

Channel pattern.—The channel pattern is developed in heterogeneous limestones, consisting mainly of calcite and dolomite. Two types of channel solution were observed in the cores etched. The first type is merely the restoration of old continuous porosity of a channel or tube-like nature.

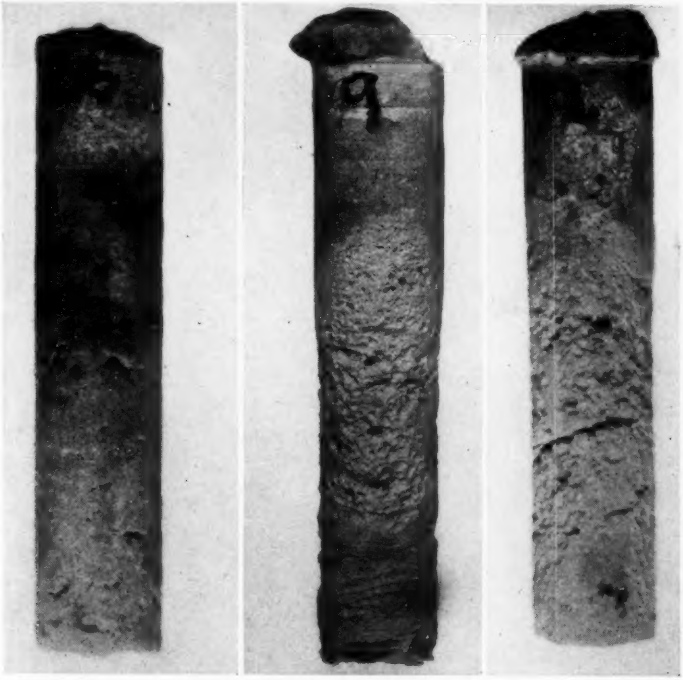


FIG. 7 FIG. 8

FIG. 7.—Channel type of solution pattern, in which former secondary continuous porosity is restored.
FIG. 8.—Cores showing development of channel solution pattern.

In this type, secondary minerals have closed off parts of the channels and have made the porosity which was once continuous, discontinuous. In limestones calcite is the most common secondary mineral with dolomite next. The acid readily dissolves the pure calcite crystals and affects the rest of the rock to a much smaller extent. Of the cores of this type treated, the striking feature was the perfect restoration of the old continuous porosity. Where secondary dolomite

FIG. 9.—Photomicrograph showing incipient development of channel type of porosity around calcite (dark). Magnification, 20 diameters.

is present, it is not dissolved as easily as calcite, and the restoration is not so perfect. These channels are complex. Air blown into one opening of a channel on one side of a core was found to come out of three other openings on the other side. Before etching with acid, this core was impervious to air. Some cores in which secondary minerals

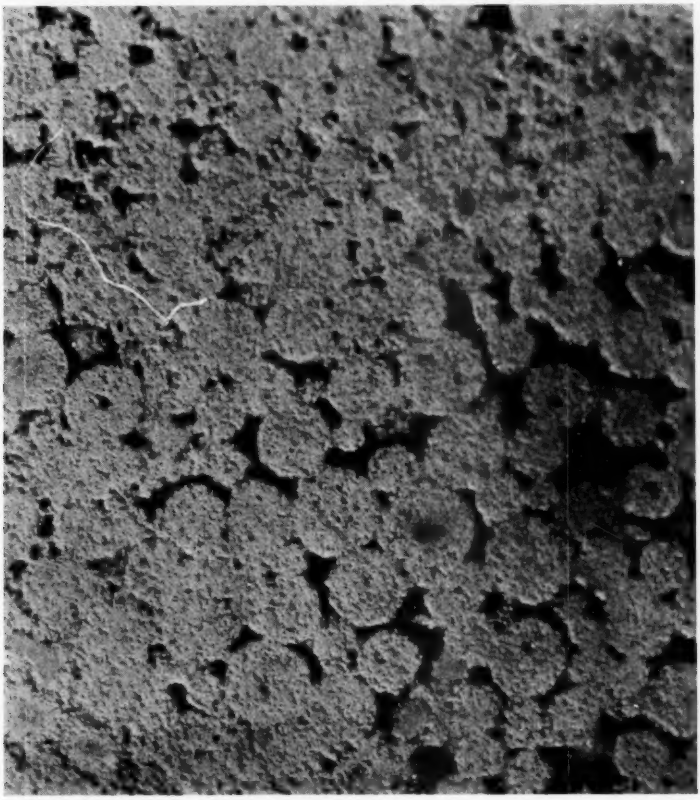


FIG. 10.—Photomicrograph of oölitic limestone showing how channel-porosity pattern might develop as result of solution of cement. Magnification, 20 diameters.

had been deposited in the channels revealed by staining that periods of dolomite deposition had taken place with later calcite, or *vice versa*. Figure 7 is a picture of an oil-stained core in which the secondary calcite has been dissolved out in the lower or lighter part of the core. The openings of the channels can be readily seen.

The other type of channel solution is of a similar nature, but represents the development of original solution channels. These channels or tubes are formed, apparently, because calcite grains are arranged in chains. Figure 8 shows small openings leading into deeper

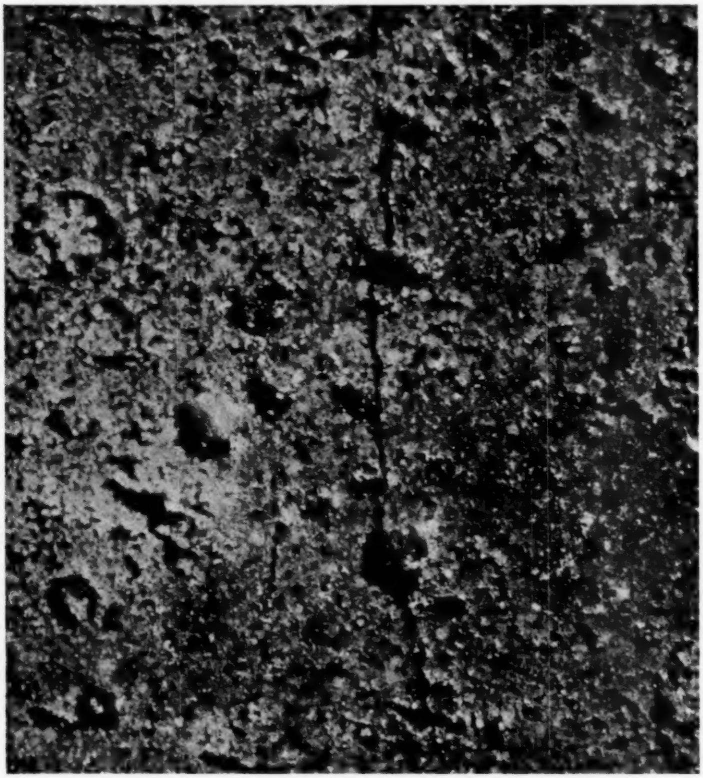


FIG. 11.—Photomicrograph showing in detail development of channel-solution pattern. Magnification, 20 diameters.

channels, while Figures 9, 10 and 11 show types of limestone in which the channel pattern develops.

The channel pattern of solution gives by far the most penetrative kind of porosity. It is, therefore, the commonest type found in oil fields where limestone forms the reservoir.

Cellular type.—The cellular pattern is typified by shallow con-

cavities formed by solution on exposed surfaces. It is apparently due to the presence of scattered soluble grains in a matrix of less soluble material. Figure 12 shows how this pattern is developed, and Figure 13 shows the type of limestone in which this pattern is likely to de-

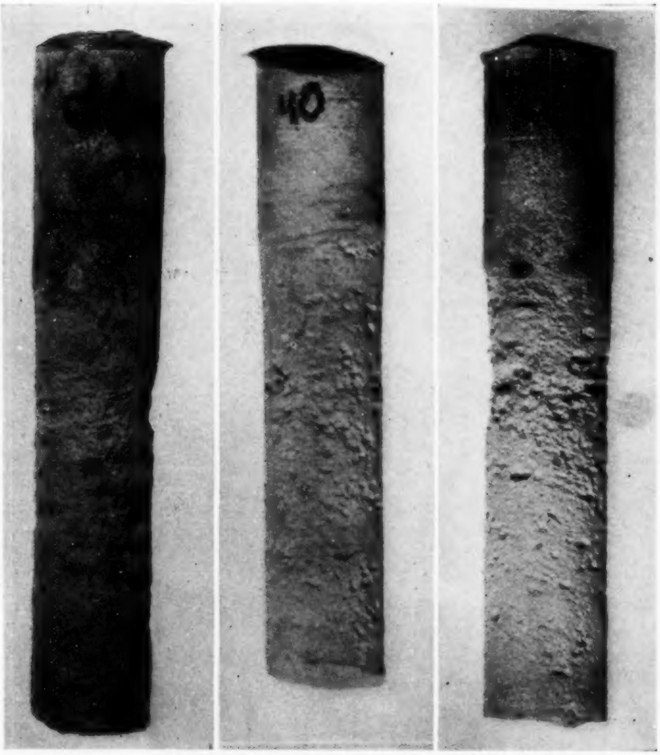


FIG. 12.—Cores showing development of cellular type of solution pattern.

velop. In places small channels are seen leading from one opening to the next, but these are usually so small, that it is questionable whether they would permit the passage of fluids.

Limestones possessing a cellular pattern alone will not develop a penetrative or continuous porosity. In combination with either the equi-solution or channel type, this would, of course, not be the case. If a limestone weathered at the surface, that is, on a horizontal plane,

the initial cavities dissolved might be good starting points for further solution, regardless of the less soluble nature of surrounding mineral grains.

Limestone which has a combination of cellular and channel porosity pattern developed within it would make a more ideal type of

FIG. 13.—Photomicrograph of limestone with disseminated calcite (light) in which cellular type of porosity pattern would develop. Magnification, 20 diameters.

potential reservoir rock, than one possessing only a cellular pattern. The interconnecting channels would have to be sufficiently large to allow the passage of fluids.

ACID TREATMENT

The most important artificial method of increasing the porosity of a limestone reservoir rock is acid treatment. It is impossible to know

just what happens in the reservoir during treatment, and only inferences based on indirect evidence can be made. Wells react differently to acid treatment, depending upon the nature of the reservoir and the method of treatment.

At the outset, it may be stated that little if any indigenous oil is released by acid treatment. It would require too great an amount of

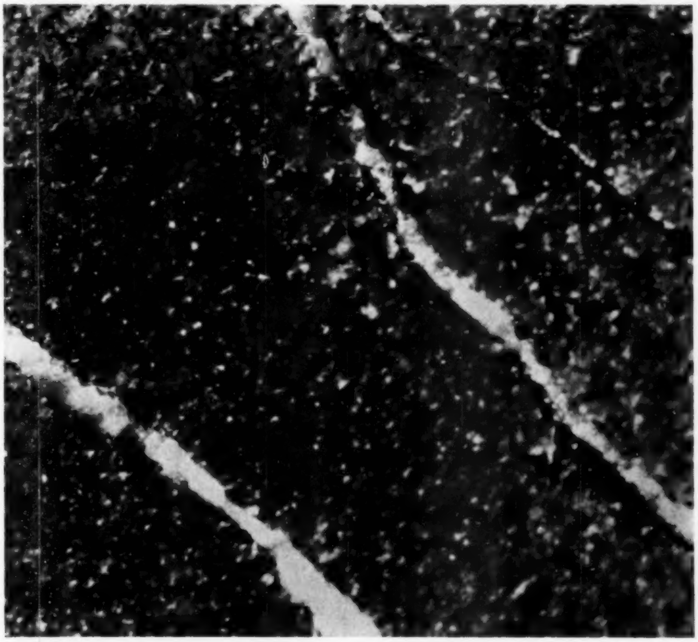


FIG. 14.—Photomicrograph showing partial filling of channel type of solution pattern by precipitation of secondary calcite. Magnification, 20 diameters.

limestone to be dissolved to reach the individual globules of oil to give an appreciable increase in production.

SECONDARY CALCITE

Little attention has been given to the part secondary calcite plays in a reservoir. However, it can not be denied that nearly every limestone reservoir of any consequence possesses considerable secondary calcite.

It is obviously possible for deposition of secondary calcite to take

place in such a way that formerly continuous porosity in the reservoir would be broken up into a number of compartments, of irregular size and shape. It is also obvious that some of these compartments might not yield their oil to the nearest well, indeed to any well, unless the wells are very closely spaced. It is believed that acid treatment is in many cases effective in removing barriers formed in this way and thus increases the drainage area of the individual wells.

In certain cases, as production after treatment rises high above the original initial production, it seems highly probable that the acid has eaten its way through secondary calcite and has brought into the area drained by the well new compartments, which were not previously in communication with any well in the field.

In other cases, the acid does not increase production above the original initial production, but does restore an appreciable percentage. Here it seems to operate in cleaning out the well, but this cleaning out may easily include the dissolving of secondary calcite. There is good evidence to believe that secondary calcite is precipitated as the oil is produced. With the development of the field, pressure decreases are likely to result in the deposition of calcium carbonate, which had remained in solution up to that time. Pitzer and West[12] note that appreciable quantities of soft limestone particles are often found in stock tanks of limestone wells. They also note that the obstructions are formed more easily as the field becomes older and the gas pressure drops. Although all the limestone particles found in the stock tanks may not be due to the precipitation of calcium carbonate, many of them are believed to be by the present writers.

RATE OF APPLICATION

Commercial practice invariably involves forcing the acid back into the formation rapidly. Pitzer and West urge speed in application, as they consider that in some limestones, presumably high in calcite, the acid will become neutralized in a very short time. The mere dissolving of the walls of the reservoir rock should not be expected to give any appreciable increases in production. It is believed that the important object is to get the acid back to the secondary calcite as quickly as possible, where it may spend itself on the secondary calcite and open up new compartments, which may contain oil and gas. If the acid is allowed to move along the old channels slowly, it may spend itself before reaching the secondary calcite. Moreover, solution of the secondary calcite gives no insoluble residue.

[12] P. W. Pitzer and C. K. West, "Acid Treatment of Lime Wells Explained and Methods Described," *Oil and Gas Jour.* (November 22, 1934).

Solution of the rest of the reservoir rock may release flocculent clays that may seriously reduce the permeability of the reservoir.

INSOLUBLE RESIDUE

One of the most serious difficulties involved in acid treatment is the release of insoluble residue from the reservoir rock proper. The insoluble residue in limestones may be roughly divided into (a) material of a constant volume and (b) swelling material. The first class consists of sand grains, chert, and other minerals not possessing a colloidal structure. The second class is represented mainly by the clay series.

The residue of a constant volume is not believed greatly to reduce the permeability of the reservoir; however, the piling up of sand and dolomite grains at small openings may seriously retard the passage of fluids. Usually, the material of a constant volume has high enough specific gravity to sink or settle to the bottom of the channels as it is released.

The clays offer the most serious trouble in respect to reduction of permeability. It has been found that the acid clays formed when limestones are dissolved may be altered very rapidly to sodium or calcium clays by base exchange and it is believed that most of the clays found in limestones which have undergone acid treatment will be of the latter type. In some cases, a sodium clay has been found to have a volume of 60 per cent of the equivalent calcium clay. The flocculent nature of the latter is also demonstrated by the fact that some calcium clays have been reduced to one-sixth of their original volume by centrifuging.

NOTE

Although it is not the purpose of the writers to discuss in this paper the origin of petroleum, it is obvious that the formation of hydrocarbons from organic material must involve hydrogenation. Since the only probable supply of hydrogen is water, the oxygen of the water must be eliminated by the evolution of carbon dioxide gas. Buswell[13] and his co-workers have done a great deal of work on the formation of methane from anaerobic fermentation of plant and animal debris, and show that the proportion of carbon dioxide to methane varies from 1:1 for simpler forms to a theoretical limit of 1:3 for an acid chain of infinite length. The average methane yield from sewage is approximately 64 per cent.

Although the formation of oil is not completely carried to methane but involves the formation of a large number of hydrocarbons, a considerable

[13] (a) A. M. Buswell, "Production of Fuel Gas by Anaerobic Fermentation," *Indus. and Eng. Chem.*, Vol. 22 (1930), p. 1168.

(b) A. M. Buswell and C. S. Boruff, "The Relation between the Chemical Composition and Quality and Quantity of Gas Produced during Sludge Digestion," *Sewage Works Jour.*, Vol. 4, No. 3 (1930).

quantity of carbon dioxide gas is evolved in excess of that required for the formation of natural gas associated with the oil. Yet, carbon dioxide is found only in very small amounts in natural gas. If it is formed in this way, and is precipitated by the reaction of calcium-bearing waters as calcium carbonate then the effect of this precipitation of calcium carbonate may be roughly estimated.

Let us assume a limestone "pay" 30 feet thick which yields 10,000 barrels of oil per acre and has an average gas-oil ratio of 3,000. The gas content of this "pay" will then be 30 million cubic feet per acre. The equivalent quantity of carbon dioxide would be about $5\frac{1}{2}$ million cubic feet per acre. If it is all precipitated as calcium carbonate, and it appears that it probably would be in a limestone reservoir, about 800 tons per acre-foot would be deposited. This would occupy about 360 cubic feet or about 0.85 per cent of the total volume of an acre-foot. If the original porosity is 20 per cent, the precipitation of this calcium carbonate would fill about 4.2 per cent of the pore space. The extent to which the permeability is effected by this deposition would depend on the places where it was deposited.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 20, NO. 11 (NOVEMBER, 1936), PP. 1413-1438, 14 FIGS.

GEOMORPHOLOGY OF GULF COAST SALT STRUCTURES AND ITS ECONOMIC APPLICATION[1]

C. H. RITZ[2]
Houston, Texas

ABSTRACT

The importance of rim synclines, around Gulf Coast salt domes, as structures affecting the migration and accumulation of oil and gas has not been generally recognized. The synclines may divert the migrating oil, in those formations old enough to be affected by subsidence into the syncline, around the dome, and on up dip. They may also overlap with synclines of other domes to form effective traps for the accumulation of oil and gas in the interdomal area. The synclines may be circular, with the dome in the center, circular with the dome in an eccentric position, or irregular in shape, depending largely on the geologic conditions affecting the migration of salt into the dome during the entire history of the growth of the dome.

Differential upward growth of the salt is believed to be caused largely by the differential rate of flow of salt into the dome. Under the resultant forces it is believed that the vertical axis of the dome may migrate a distance as great as the radius of the dome. Such migration of the vertical axis is of interest to the geologist primarily because of the effect it may have on the structure of the oil-bearing formations.

INTRODUCTION

Subsurface studies in the Gulf Coastal area indicate the existence of some rather unexpected and unorthodox types of structure. The Empire Oil and Gas Company's Kunze No. 1 well, on the east side of the San Felipe salt dome, encountered the McElroy formation approximately 2,000 feet lower than it would normally be expected. The Humble Oil and Refining Company's Warren No. 7, on the northeast flank of the Hockley dome, is apparently about 1,300 feet below normal and the Graham *et al.* Hagar No. 1 about 5 miles farther north is approximately 1,500 feet low.

Southwest of the Hockley dome and east of the San Felipe dome, in the interdomal area, the Stanolind Oil and Gas Company-Amerada Petroleum Corporation's Thorpe No. 1, although apparently about 200 feet below normal, is a gas well.

It is believed that rim synclines, peripheral faulting, and other

[1] Manuscript received, August 5, 1936.

[2] Geologist, Republic Production Company. The writer, fully realizing the highly controversial aspects of this paper, as well as the lack of definite proof of some of the theories postulated and conclusions reached, has called on many of his Gulf Coast associates for criticism of his conclusions. He is particularly indebted to Donald C. Barton and Sidney Judson for helpful suggestions, and to Paul Weaver, R. L. Beckelhymer, L. P. Teas, and F. X. Bostick for their kindness in reading and criticizing the paper.

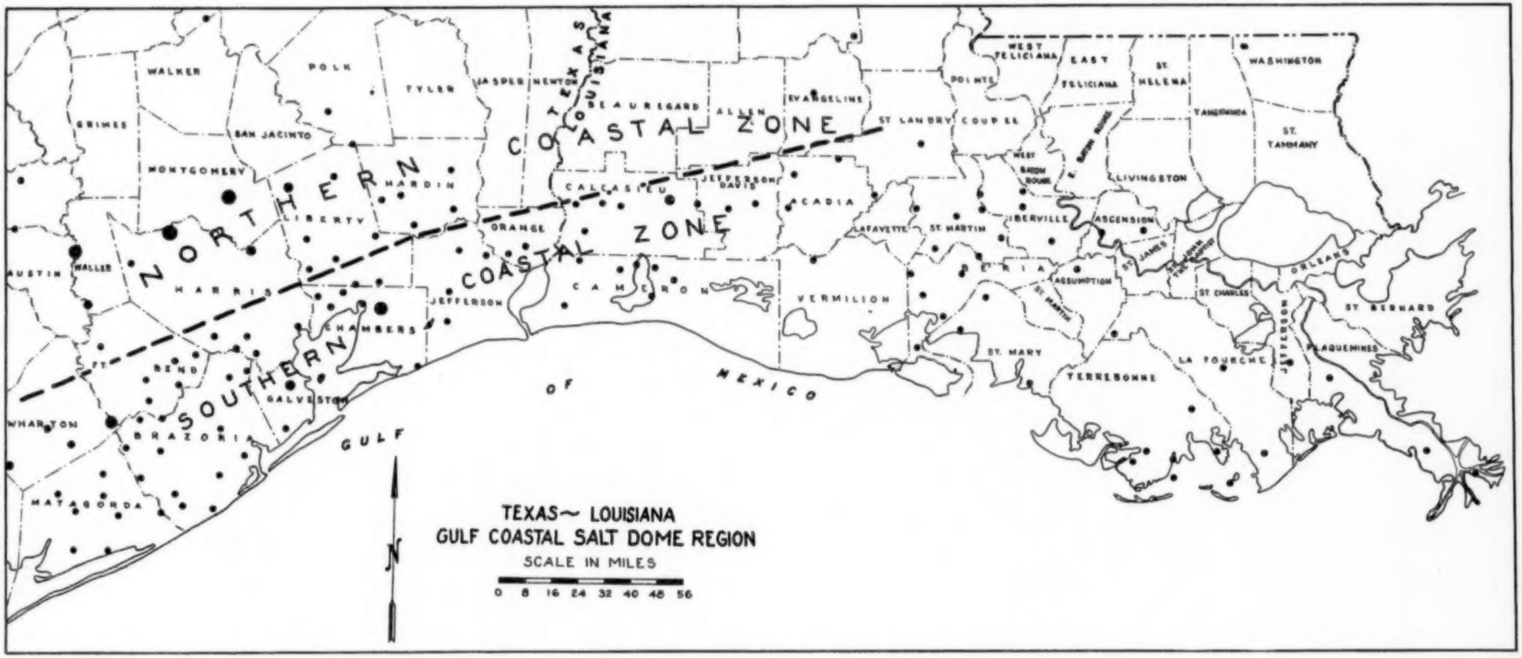


FIG. 1.—**Texas-Louisiana Gulf Coast salt-dome region.** Heavy broken line separates northern coastal zone, in which McElroy formation of Jackson age is used as key horizon, from the southern coastal zone, where top of *Heterostegina* horizon of Oligocene age is used. Black dots indicate known salt domes, the diameter being a rough index of size of dome.

structural features associated with subsidence are not sufficiently considered by Gulf Coast prospectors for oil. It is therefore, deemed essential to point out certain interesting facts as follows.

1. All the salt domes located in the northern coastal zone, an area in which the top of the McElroy formation can be used as a key horizon for regional subsurface studies, seem to show evidence of subsidence of the formations below normal in the vicinity of the uplift. Figure 1 shows the location of Gulf Coastal salt domes and the approximate boundary between the northern and southern coastal salt-dome zones. The division of the province into zones is based solely on the fact that in the northern zone older formations, which seem to show greater evidence of subsidence, are within reach of the drill.

2. Large shallow domes would require the migration of larger volumes of salt; hence, they would have the largest synclines and best developed peripheral faults. Most of these domes have not been profitable oil fields.

3. Rim synclines on the domes located in the southern coastal zone, where subsurface data on only the younger formations are available, have probably been overlooked due to: (a) lack of synclines in the younger formations due to depositional filling of the synclines by thickening of the formations in the synclinal area during the period of development of the dome and its associated syncline; (b) lack of paleontological data due to great depth to a dependable horizon marker of sufficient age to have been affected by the subsidence of the formations into the syncline; (c) lack of paleontological data where synclines exist due to the lack of deep wells slightly away from the dome; and (d) misinterpretation of existing data.

Unfortunately for the geologist attempting to solve such problems, wells are drilled for oil rather than scientific information; therefore, many of the structural features of the formations around salt domes will probably never be discovered.

The problem of origin and mechanics of salt-dome intrusion has been studied and described by L. L. Nettleton[3] whose article furnished much of the basic theory for this dissertation.

THEORY OF FORMATION OF SALT STRUCTURES

Nettleton arrived at the following conclusions.

1. The prime motive force for the formation of domes is the density difference between the salt and the surrounding sediments.

[3] L. L. Nettleton, "Fluid Mechanics of Salt Domes," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 18, No. 9 (September, 1934), p. 1175.

2. Both the salt and the surrounding sediments behave as highly viscous liquids and flow slowly through long geologic time.

These conclusions are believed to be amply supported by his experimental data as well as by available geological information and are believed to be sound in theory. The reader is referred to Nettleton's article for a detailed description of the history and mechanics of salt-dome intrusion.

Figure 2 is a picture of a wax model, formed in one of Nettleton's experiments, which has been sliced in half along the vertical axis. Notice that the vertical axis of the dome has shifted from its initial position at the center of the disc and that the peripheral sink is widest and deepest on the side away from which the dome has shifted (see also Fig. 10).

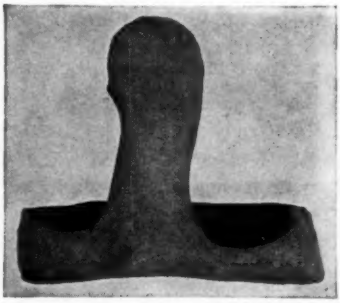


FIG. 2.—Wax model dome formed in experiment by L. L. Nettleton, sliced in half along vertical axis. (From L. L. Nettleton, "Fluid Mechanics of Salt Domes," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 18, No. 9, September, 1934, p. 1189, Fig. 4.)

The term peripheral sink, as used here, applies to the space evacuated by the migrating salt and the term rim syncline is used to describe the effect of the peripheral sink on the overlying sedimentary formations.

EXTENT OF PERIPHERAL SINKS

The following calculations, in which the Hockley dome is used as an example, illustrate the probable size of rim synclines.

By using the average diameter of $2\frac{1}{2}$ miles and by assuming a cylinder of salt 4 miles in height, it is obvious that approximately 20 cubic miles of salt would be required to build the Hockley dome.

If the existence of a mother salt bed, 1,500 feet in thickness (the apparent amount of subsidence as indicated by contours on the McElroy formation) is assumed, an area of 70 square miles of mother

salt bed would be required to furnish the necessary salt for the formation of the Hockley dome, provided the extraction of the salt was 100 per cent effective.

The extraction of this salt would form a peripheral sink 1,500 feet in depth, and if the area were circular in form, it would have a radius of approximately 5 miles from the center of the dome to the outer edge of the sink. However, as it is extremely improbable that all the salt would be extracted, especially near the outer limits of this circle, or that extraction would be uniform on all radii, it seems highly probable that salt migrated into the Hockley dome from distances as great as 8–10 miles on some of the radii.

Inspection of Figure 8 reveals that a syncline of this depth does extend at least 5 miles northeast, although its depth in other directions is unproved or of a lesser order.

The use of the proved amount of subsidence on the McElroy formation in the vicinity of the Hockley dome, for calculations to arrive at the probable size of the peripheral sink, may well be questioned by the reader. It is highly probable that the McElroy formation was not subject to the full amount of subsidence affecting the older formations lying nearer the top of the mother salt bed, due to prior depositional thickening of those older formations within the area of the peripheral sink. It is also probable that the maximum subsidence of the McElroy formation in this area has not been proved. If this greater subsidence could be proved it would necessitate a greater assumed thickness of mother salt and a decrease in the necessary area of the peripheral sink to furnish the salt for the building of the dome.

On the other hand, the Hockley dome has a cap-rock formation approximately 900 feet in thickness. The generally accepted secondary theory of origin of the cap rock, involving solution of the salt of the upper part of the dome and leaving the insoluble residue (mostly anhydrite) as a cap on top of the dome, would require the solution of about 18,000 feet of salt containing 5 per cent impurities from the top of dome and nearly double the calculated amount of salt necessary to form the dome and its overlying cap rock. Therefore, it is believed that though it is highly probable that the thickness of the mother salt bed exceeded 1,500 feet, it is also highly probable that the amount of salt necessary to form the dome and its associated cap rock is also considerably greater than the figures used.

The San Felipe salt dome probably contains more than twice the volume of salt found in the Hockley dome and the area of its rim syncline would therefore be correspondingly larger than that of the Hockley syncline.

Subsurface studies indicate that the Raccoon Bend syncline extends to a distance of approximately 11 miles on the northwest flank.

The foregoing calculations are admittedly highly qualitative. Careful consideration of the probable accuracy of the assumptions, on which quantitative calculations could be based, indicates that the probable error in basic assumptions would be sufficiently large to render valueless the results of any refined quantitative calculations.

The following assumptions may vary to a very high degree.

I. Volume of salt in the dome depending on:
  A. Distance from top of dome to base of mother salt bed
  B. Form of dome at depth
    1. Cylindrical
    2. Cone-shaped with apex at top
    3. Inverted tear-drop shape
II. Volume of salt, now dissolved away, necessary to form anhydrite cap rock
III. Thickness of mother salt bed
IV. Percentage of available salt removed from mother salt bed, depending on distance from dome if uniform withdrawal on all radii is assumed
V. Probable highly erratic nature of salt flowage from mother salt bed into dome as indicated at Raccoon Bend

Nevertheless, it is believed that serious consideration of the theories involved will be of great assistance to the subsurface geologist in his interpretation of well data in the Gulf Coast or in any other salt-dome province.

EFFECT OF RIM SYNCLINES ON OIL MIGRATION

Figure 3 is a diagram illustrating the effect of the uniform withdrawal of 1,000 feet of salt from beneath a given sedimentary plane which has a regional dip of 120 feet per mile. The calculated amount of salt necessary to form a dome one mile in diameter was withdrawn. In this diagram the uplift of the formations by the dome has been disregarded in order to study only the effect of the peripheral sink upon an inclined plane of sediments.

It is evident that oil, migrating updip in this formation, would be diverted away from the dome by the rim syncline and that sufficient uplift of the formations by the dome to overcome the effect of the sink on the downdip side, erratic development of the syncline, or filling of the syncline by depositional thickening of the older formations would be necessary to permit migration of oil into the trap around the dome.

An analysis, for the purpose of studying the effect of doming on the overlying sediments, reveals that if 1,000 feet of subsidence in the synclinal area as in Figure 3 and 1,200 feet of uplift due to doming take place simultaneously, a pattern similar to Figure 4 will result. Approximately 500 feet of barrier ridge exists on the downdip side

to divert migrating oil elsewhere, due to the fact that the major uplift of the formations has taken place close to the dome while the outer edge of the syncline, where sediments are likely to be more affected by subsidence than uplift, lies 2–4 miles from the dome. Dashed circular contours represent assumed 100-foot contours on uplift of the formations, due to doming. Heavy lines represent resultant contours on sediments after subsidence into the peripheral sink and uplift of the sediments by salt are superimposed on the regional dip. The arrows indicate the course of the migrating oil. A well located at *X* would be structurally located in a position similar to the wells on

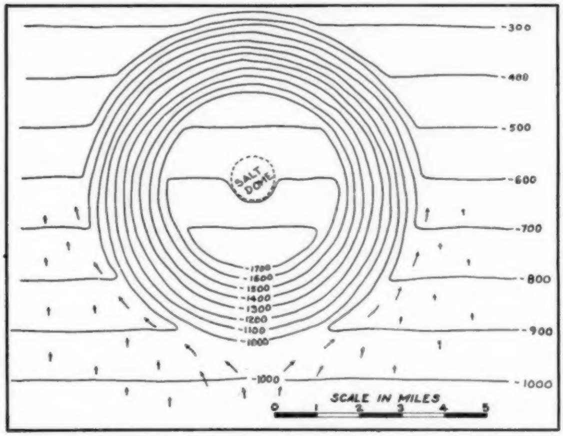


FIG. 3.—Diagram showing effect of uniform withdrawal of 1,000 feet of salt from beneath a given sedimentary plane with regional dip of 120 feet per mile.

the Ogburn prospect, with reference to Hockley dome, both in Harris County, Texas; also, wells at *Y* would be structurally low, while at *Z* they would be high, yet none is close to the dome. The high areas labeled *X* and *Z* are due to the fact that the assumed area of uplift exceeded the calculated area of the peripheral sink.

It is obvious that, in an area affected by domal uplift of the sediments or peripheral sink, the relation between the subsurface elevation of the key horizons and the regionally normal position of those horizons at a given location will depend on: (1) the amount of uplift due to the near-by dome; and (2) the amount of subsidence due to the extraction of the underlying mother salt and the amount of depositional filling of the syncline.

It is also believed, however, that such conditions as exist in the vicinity of *X*, particularly warping and weakening of overburden, would be favorable to the initiation of another salt dome, probably of a deeper type due to lack of salt on one side. In other words, there are two possibilities: (1) Ogburn is a deep dome of which Hockley is the parent; (2) Ogburn is a residual nose and doming is not present.

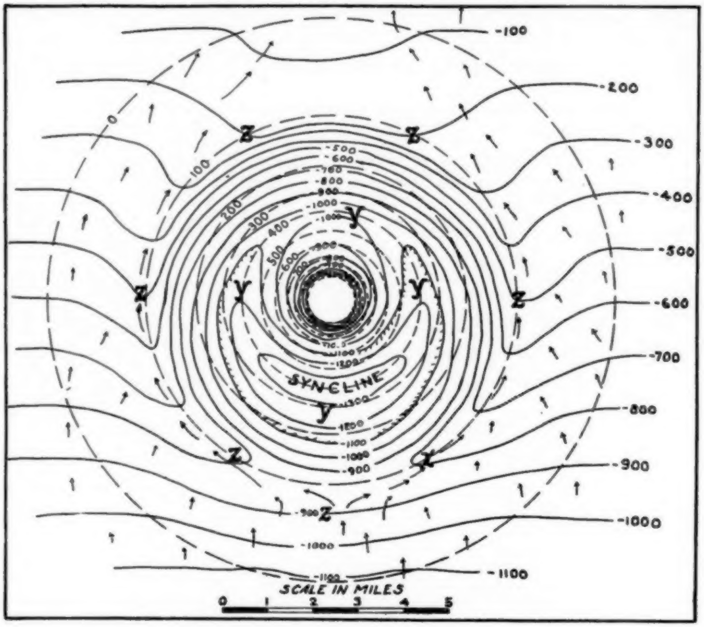


FIG. 4.—Diagram showing result of 1,000 feet of subsidence in synclinal area as in Figure 3 and 1,200 feet of uplift due to doming taking place simultaneously.

It must be remembered that Figure 4 is a hypothetical case—that is, only 1,200 feet of uplift on the sediments was used where the maximum possible ranges from several thousand feet on the deeper formations to a few hundred on the shallower formations. The average probable subsidence of 1,000 feet was used. Therefore, Figure 4 is a diagram which, it is believed, illustrates the probable basic form of which there would be countless variations, depending on the relation between subsidence and uplift.

Though large shallow domes tend to form large peripheral sinks

and large rim synclines with complicated faulting, which on the whole make such areas unfavorable for prospecting, nevertheless it is believed that there will be plenty of traps which will hold oil if the oil can move to them instead of being diverted elsewhere by the rim syncline.

Such conditions are shown in the accompanying diagrams (Fig. 5). The decrease in volume of the dome at depth, due to the flow of salt upward from the base of the dome after the supply of salt from the

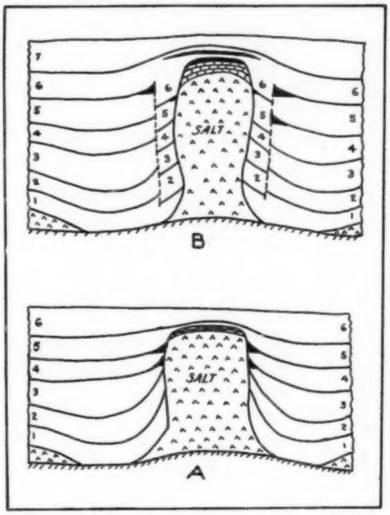


FIG. 5.—Diagrams showing how decrease in volume of dome at depth causes slippage of abutting formations downward along dome and severe faulting to great depths. (Revised after Nettleton.)

mother salt bed has been shut off by subsidence of the overlying formations, would give a greater tendency for slippage of the abutting formations downward along the dome, and severe faulting carried to great depths.

Possible traps for oil are indicated. Those inside the faults at depth are likely to prove of minor importance. The most favorable traps will be those in the younger formations which have been less severely folded and faulted and less affected by subsidence into the sink.

The possibility of commercial production in formations most affected by subsidence into the peripheral sink will probably be small due to the small area of drainage within the limits of the rim syncline.

Though it is not claimed that economic production of oil on these domes will never be found, it is believed that existing subsurface evidence indicating large deep rim synclines makes prospecting on such domes extremely hazardous from the economic viewpoint.

Other domes, in addition to Hockley and San Felipe, which probably belong to this category, are Brenham, Davis Hill, and Pine Prairie. There are many large domes in the lower Gulf Coast area, such as Stratton Ridge, Boling, and Fannett in Texas, and the Five Islands, Fausse Point, and others in Louisiana, whose poor production records may be, to some extent, a result of their association with rim synclines. Wendtland and Knebel[4] list 13 interior basin domes of East Texas, most of which are notoriously dry, as having well developed or partially proved rim synclines.

It seems highly probable that some larger domes, as South Liberty, Humble, Barbers Hill, and Hull, have not progressed beyond stage *A* of Figure 5, and good flank production is found as indicated. The synclines of these domes must be ineffective on the downdip side either through erratic development or domal uplift sufficient to overcome the effects of the subsidence, as all have been good oil producers. However, where stage *B* has been reached, flank concentration of oil in the deeper formations is likely to be sealed off from the dome by the peripheral faulting or diverted on updip by the rim syncline, to be caught in some more favorable trap.

There is a distinct possibility that oil in the older formations could have migrated into the domal trap prior to the sufficient development of the rim syncline to cause diversion of the oil away from the dome—that is, structural conditions in Cockfield time may have been such that the upper Saline Bayou formation occupied a structural position similar to the Miocene formations on present coastal-type domes. Under such conditions, accumulation could have taken place, unaffected by the later development of rim synclines and peripheral faulting.

There is also the possibility that the area of drainage, included within the boundaries of the rim syncline, may be sufficiently large to supply an adequate source of commercial quantities of oil to the domal trap in the center. This problem, though important, is beyond the scope of this article.

The fact remains, however, that on shallow domes, those which have experienced considerable uplift, the older formations have not

[4] E. A. Wendtland and G. Moses Knebel, "Lower Claiborne of East Texas, with Special Reference to Mount Sylvan Dome and Salt Movements," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, No. 10 (October, 1929), p. 1347.

proved good oil-producing horizons. Also, although the Cockfield formation is prolific on large deep domes of the Conroe type where total uplift is relatively small, it is not a good producing horizon on the shallower types, for example, Humble, Davis Hill, Hockley, and San Felipe. This is probably partially, but certainly not wholly, due to sand conditions.

It is also difficult to understand why, with the excellent showings in the upper Saline Bayou formation in the Katy and Hardin areas, this formation is not a good producer in the Conroe and Tom Ball areas where structural conditions are evidently much superior, unless possibly the rim synclines in the Conroe and Tom Ball areas have been more effective in these deeper sands in preventing the oil from reaching the structure.

POSSIBLE STRUCTURAL TRAPS AS RESULT OF OVERLAPPING RIM SYNCLINES

Figures 6 and 7 are the result of theoretical studies of the probable residual effects of overlapping salt-dome peripheral sinks on the overlying sediments. The basic assumptions, that the salt, now in the form of domes, originally occurred as a flat sedimentary bed and that the domes are a result of flowage of the mother salt bed, seem sufficiently well proved. Nettleton's calculations on flowage seem mathematically sound and in accord with the known geological facts and theories. Therefore, the use of his calculations seems justified.

However, though the theories and facts seem to be in perfect accord, great caution should be used in the application of these theoretical studies. The forces at work to produce certain results can be recognized and measured under perfect laboratory conditions, but the same forces may work very erratically under actual field conditions.

These studies assume a flat sedimentary plane dipping 120 feet per mile (top of McElroy formation) from beneath which salt has been extracted in the vicinity of the domes, for their formation. It was assumed that all of the uplift of this horizon, due to doming, occurred within the area of the peripheral sink and consequently had no bearing on this problem. Therefore, only subsidence, due to the sinks, was considered and the contours as shown within the areas of the synclines mean that the datum horizon would be found at this elevation only in case the dome had perfectly pierced the overlying sediments without causing uplift (Fig. 3).

Figure 6, a study of the effects of removal of the necessary mother salt to form the Raccoon Bend, San Felipe, Hockley, Tom Ball, and

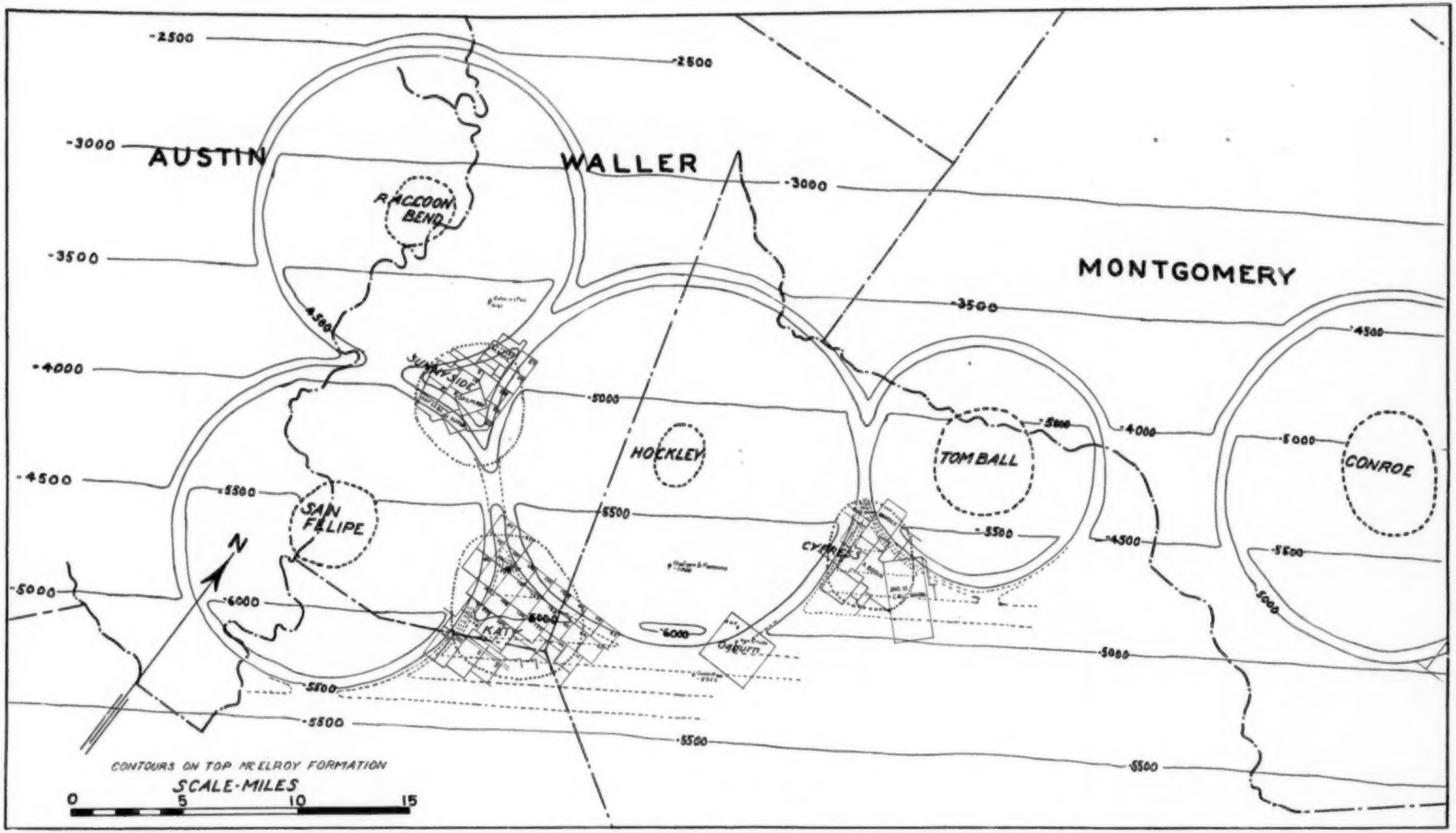


FIG. 6.—Theoretical study of probable effects of removal of necessary mother salt to form Raccoon Bend, San Felipe, Hockley, Tom Ball, and Conroe domes indicates possible residual "highs" in vicinity of Katy, Sunnyside, and Cypress.

Conroe domes, indicates possible residual "highs" in the vicinity of Katy, Sunnyside, and Cypress. Of these possible prospects, Katy is probably the best due largely to the favorable showings in the Thorpe well.

Seismograph reflection shooting is said to show favorable indications at Katy and Sunnyside, and a reported torsion-balance minimum anomaly indicates possible structure either of the type of the residual "high," or the residual "high" with subsequent doming at Cypress.

The Ogburn prospect seems to have no economic significance, the apparent "high" being caused by the syncline farther north.

Figure 7 illustrates a theoretical study of the effects of the removal of the calculated amount of salt necessary to form the Davis Hill, Hull, and South Liberty domes in Liberty County, and the Batson, Saratoga, and Sour Lake domes in Hardin County, Texas. Great difficulty was encountered in the effort to determine the normal position of the original McElroy plane prior to uplift by the domes and subsidence of the McElroy formation to form the synclines. Because many large domes exist in this area, each surrounded by its syncline, subsurface data on available wells indicate the presence of a regional syncline. Therefore, the normal contours on the top of the McElroy, had to be projected into this area from a considerable distance on either side of this area.

All wells, in the general Hardin field area (Fig. 7), with the possible exception of the three field wells, are structurally below normal. Therefore, the synclines must extend beyond their calculated limits. It is obvious that the calculated peripheral sink of the Saratoga dome would remove salt from the area needed to supply salt for the Batson dome. Therefore, it seems logical to assume that the Batson sink extends farther west and northwest than the calculations indicate.

RESIDUAL-HIGH OIL FIELDS AS A RESULT OF OVERLAPPING RIM SYNCLINES

The possibility of producing oil or gas on residual "highs" between, and downdip from, overlapping salt-dome rim synclines seems greatly enhanced by the gas and distillate production from the Stanolind-Amerada's Thorpe No. 1 well in Waller County and the oil production in Frazier's Lynott and Buffum No. 2 well in Liberty County, Texas. Both of these areas are considered to illustrate this type of structure.

The accompanying map (Fig. 8) shows the probable position of

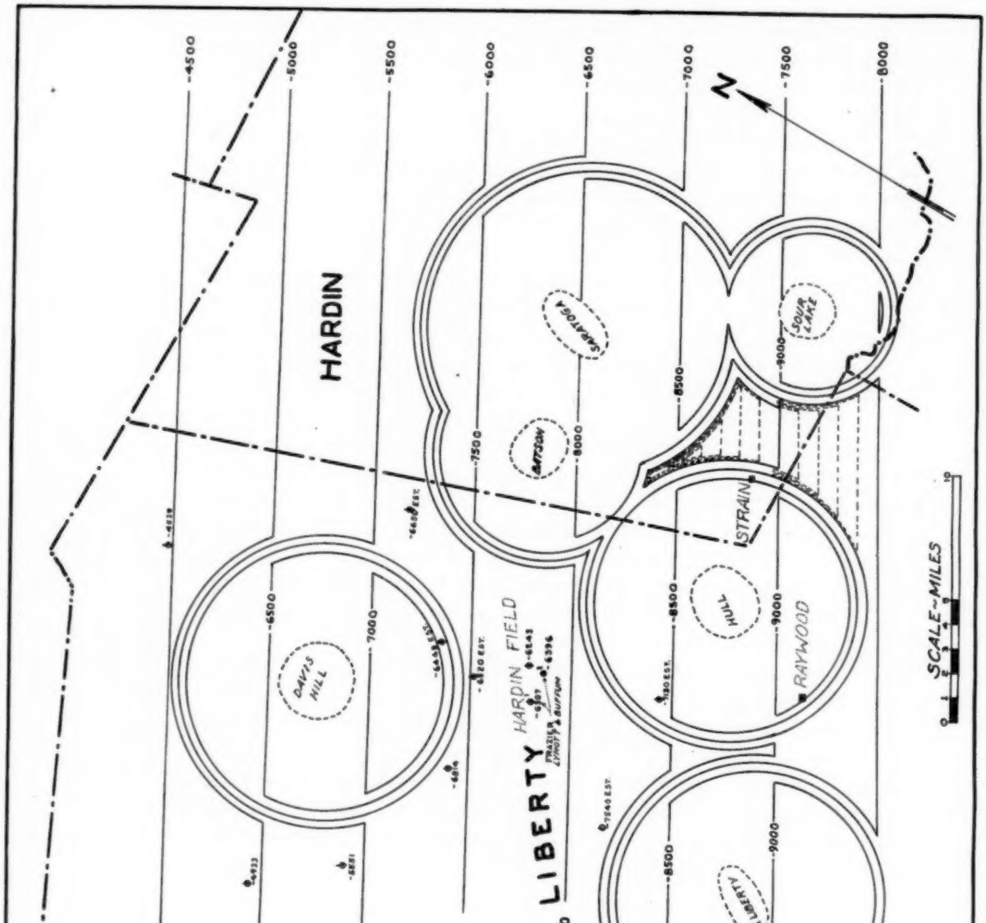


FIG. 7.—Theoretical study of effects of removal of calculated amount of salt necessary to form Davis Hill, Hull, and South Liberty domes, Liberty County, and Batson, Saratoga, and Sour Lake domes, Hardin County.

residual "highs" in the southern Waller County area. Although control is admitted to be poor and the possibility of error in interpretation great, due to the probability of erratic structural conditions, this map is believed to present a qualitatively correct interpretation of the available data in accord with the previously stated theories.

Structures of this type would be expected to be gentle and of large dimensions with more uniform sand conditions than those usually found on salt domes. Reversal on the north edge might vary from 0 to 2,000 feet, depending on the amount of salt extracted to form the adjoining domes.

It should be remembered that the rim synclines are most probably irregular in shape due to: (1) the nature of the initiating force; (2) relative thickness of the mother salt bed; (3) faulting involving the mother salt bed; (4) distribution of anhydrite associated with the mother salt bed; and (5) distribution and competency of the overlying beds.

Notice the irregular development of the syncline northwest of the Raccoon Bend oil field.

Figure 9 shows a subsurface map of the Liberty-Hardin County area which is based on the theory of Figure 7, but is governed by subsurface data where available. The structure of the Hardin area, as mapped, indicates clearly the nature of the trap and how it is possible, in the Gulf Coast, to produce oil from sands at their normal elevation without shoreline lensing-out of the sands.

Other possible traps are shown in the vicinity of Strain and Raywood, the former being considered the more favorable.

Subsurface data indicate a fault between Frazier's Lynott and Buffum No. 1 and No. 2. Theoretically, it seems that the probability of faults on this type of structure would be slight. However, faulting has been established in two of the three wells in the Hardin field; also, Sidney Judson showed the writer a surface map on another structure believed to be of this type which showed a rather complex system of faults expressed in the surface formations. Therefore, it is probable that faulting will be commonly found on residual-high structures.

Torsion-balance studies of the Hardin area indicate a fair probability that the torsion balance may be of some assistance in locating and determining the relative favorability of such prospects. It is believed that exploration in such prospective areas would prove of considerable value.

Seismic reflection work should be the most adaptable method of geophysical exploration for use in detailing such prospects.

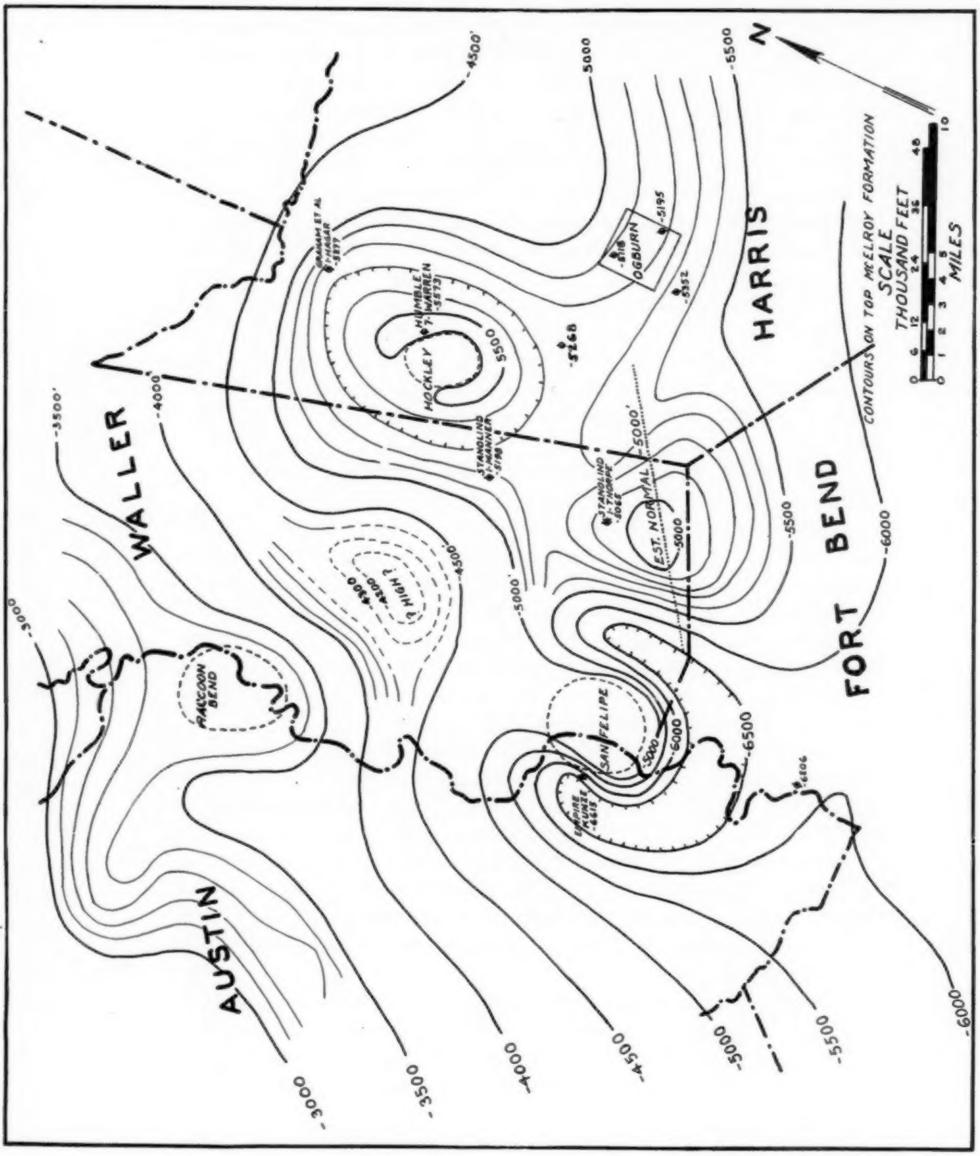


FIG. 8.—Probable position of residual "highs" in southern Waller County area.

Interpretation of both types of geophysical work should be made with a clear understanding of the probable structural form and history of this type of prospect.

It is evident that, as the closure on the formations of a residual salt structure increases with depth, production may be obtained at any depth above the mother salt bed. Therefore, the only lower limit to possible production is the depth to which the drill can penetrate and find oil-bearing sands.

On the other hand, though oil-bearing sands may exist at great depths in the vicinity of salt domes, the rule is, the older the formation, the less probability of commercial production, due to the more pronounced sink at depth to deflect the oil from the dome.

It is evident, also, as the older formations are most affected by the peripheral sinks, that the northern zone of domes constitutes the most favorable hunting ground for this type of prospect, because in this area the older formations are within reach of the drill.

DIFFERENTIAL UPLIFT OF SALT

It is interesting to analyze the probable effect of the differential uplift on the sediments. (By differential uplift is meant the faster growth of the dome on one side than on the other side, Figure 10-B.) As Figures 10-A and 10-B are profiles at right angles to each other, neither shows the maximum shift of the vertical axis of the dome or the maximum and minimum development of the sink.

In this illustration the solid lines were drawn to indicate the probable intermediate stages of growth of the dome between Nettleton's No. 3 and final stages, the dash-dot lines to represent the probable position of the sediments as affected by the uplift, and the dashed lines to represent the direction along which force is being applied, the length of the dashed lines, in some measure, representing the rate of growth of the dome along that line.

It now becomes necessary for the reader to form a clear mental picture of the forces at work. Imagine the salt in position "1-original" (Fig. 10-B), with the sedimentary layers 1, 2, and 3 gently arched by the slight uplift. Let the uplift continue to stage 3 and notice here that the distance XX' along line 3 has lengthened considerably over line 1 (the additional distance on the diagram would represent about 1,800 feet under actual conditions).

It is obvious that one or two things or a combination of them must occur. The overlying sedimentary layers 1, 2, and 3 must be stretched, with consequent thinning, or the arch of sediments must be broken to allow penetration of the salt. It is highly probable that this break-

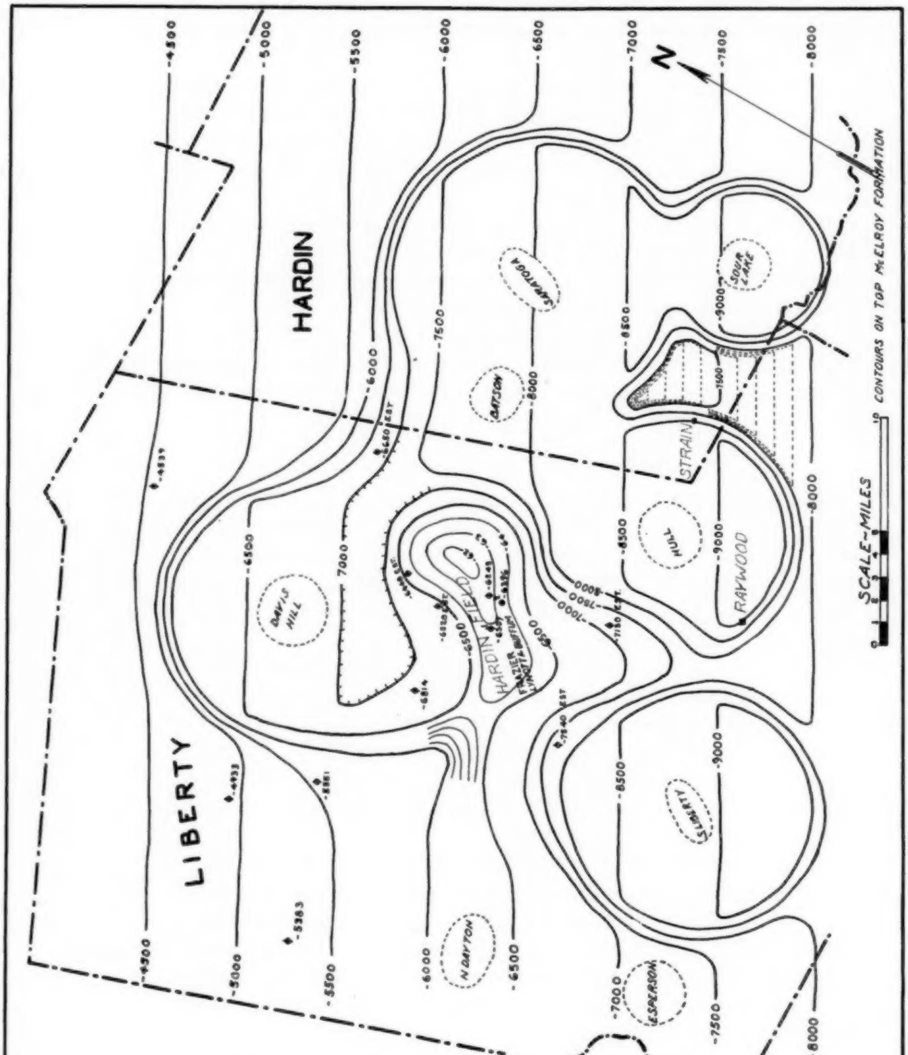


FIG. 9.—Subsurface structure of Liberty-Hardin County area, based on theory of Figure 7, but governed by subsurface data where available.

age occurs near stage 3, at, or slightly at the left of, the high point (because the dome is growing upward fastest, and toward the right on the upper left side of the dome). This causes stretching of the formation on the left and compression on the right until the break in the sediments occurs. (It is not contended that actual compression of the sediments occurs, as relief from compression is easily found through uplift.)

If point *Y* is now regarded as a hinge point and the dome is imagined to grow upward and toward the right, the formations 1, 2, and 3 on the right side will be uplifted at right angles to the lines of force (dashed lines) with probable consequent stretching and thinning close to the salt.

The beds on the left, however, slump farther and farther into the deep syncline as it develops, very little uplift being necessary due to the increasing space available for them along the bottom of the sink and in the space vacated by the dome.

It is assumed that sedimentation, uplift, and subsidence into the sink occurred simultaneously during the deposition of the beds 4 and 5. The rim syncline is overcome by depositional thickening of the sediments in the sink.

During stages 6 and 7 there will be additional growth of the dome upward and toward the right with consequently greater uplift of sediments on the right side of the dome.

Application of these observations to actual domes indicates: (1) that the sink is likely to be better developed on one half of the periphery than on the other; and (2) that the sediments will be uplifted asymmetrically on the side opposite the well developed sink.

It seems reasonable to believe that if these tendencies to eccentric formation of uplift occur under such ideal conditions where the overburden (mercury) is uniform in density and competency, that under actual conditions of greatly varying density and competency, plus other probable irregular structural or sedimentary conditions, a vertical uplift of the salt probably would be the exception, rather than the rule.

It seems probable that differential uplifting and migration of the vertical axis of the dome away from the side of best developed sink is an effect of faster migration of the salt into the dome from one side than from the others, due to erratic geologic conditions.

Possible retarding influences on the rate of flowage of salt into the dome are: (1) faulting involving the mother salt bed; (2) thinning of the mother salt bed caused by conditions of deposition and previous

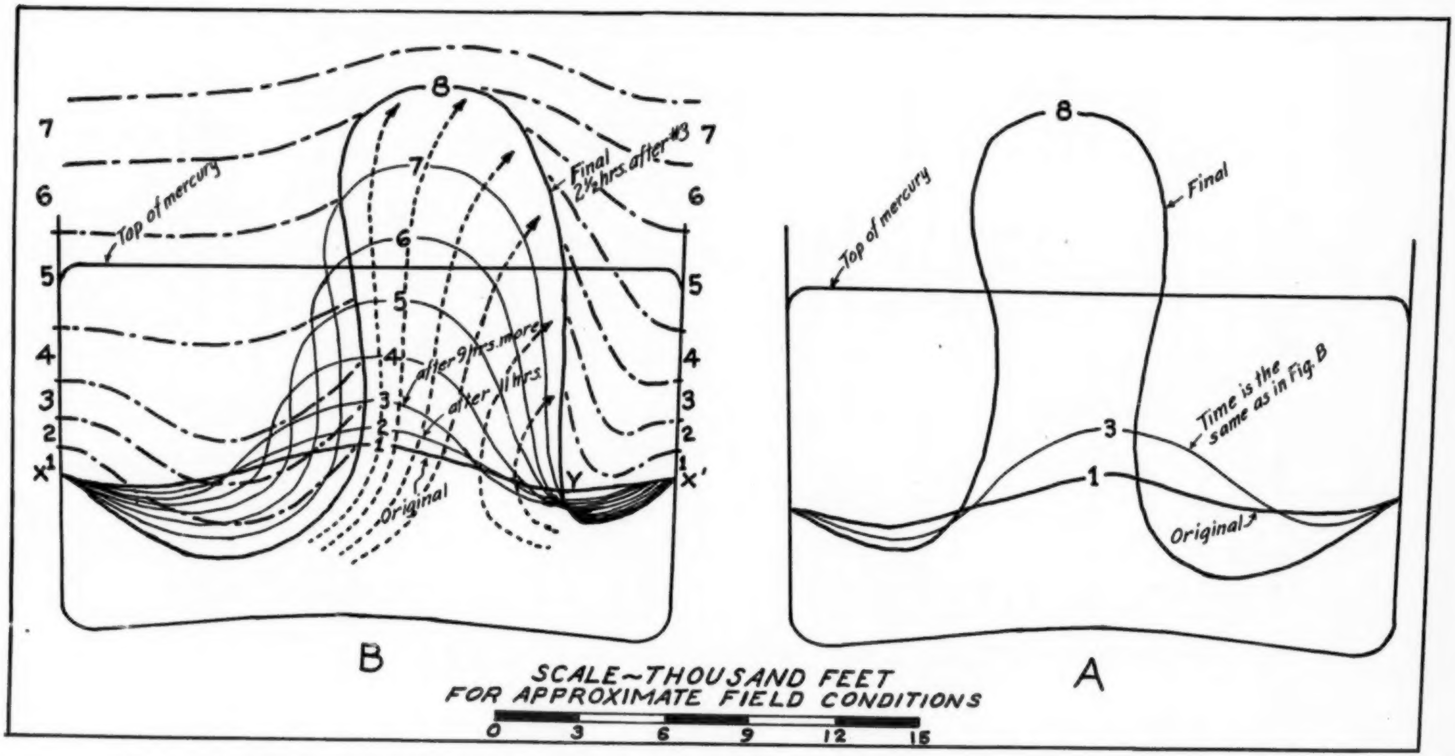


FIG. 10.—Diagrams—profiles at right angles to each other—showing probable effect of differential uplift on sediments. (Revised after Nettleton.)

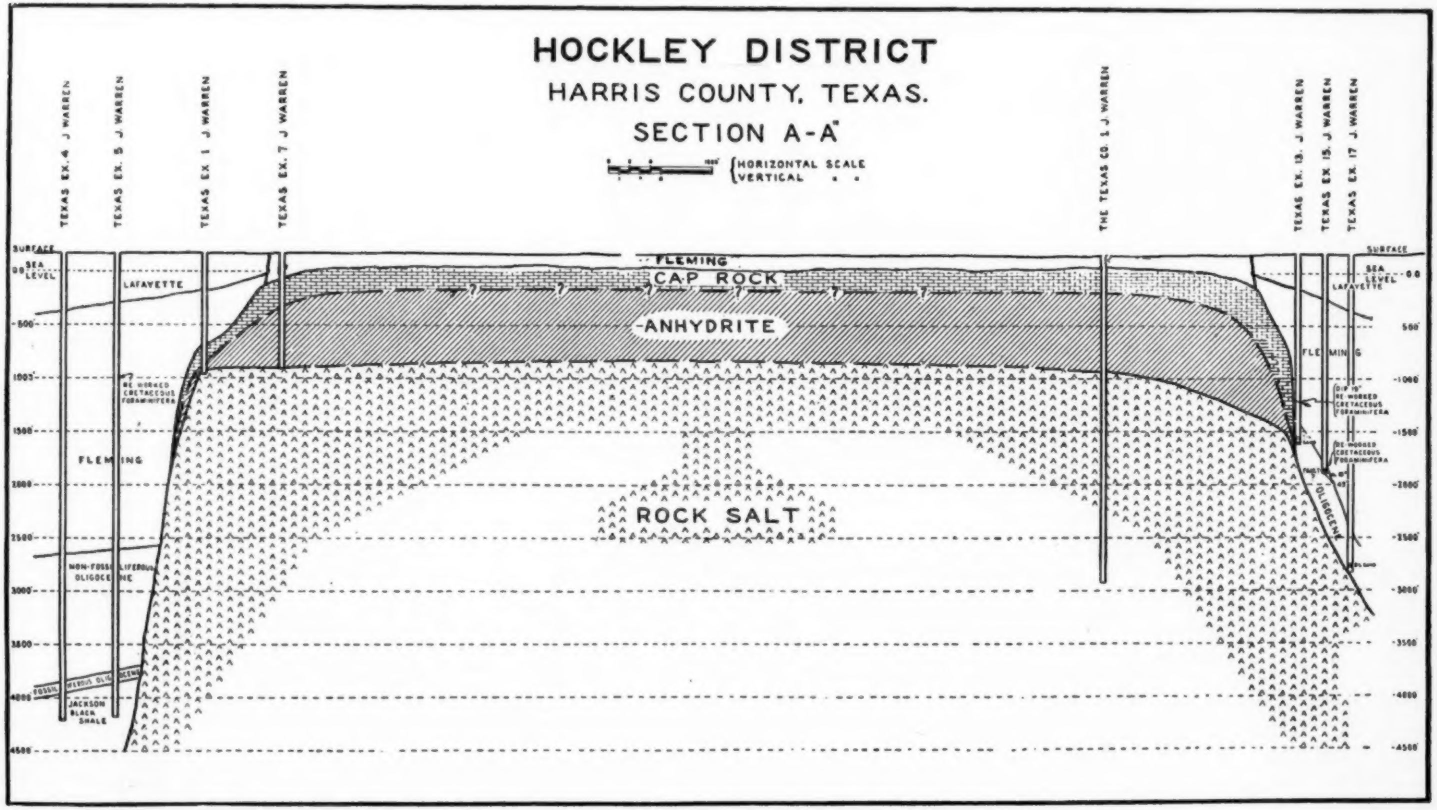


FIG. 11.—Profile across Hockley dome illustrating effect of differential uplift on penetrated formations. (From Alexander Deussen and Laura Lee Lane, "Hockley Salt Dome, Harris County, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 9, No. 7, October, 1925, p. 1040, Fig. 3.) Location of profile shown in Figure 12.

extraction of salt from one or more sides to form neighboring domes; and (3) distribution of associated anhydrite or gypsum deposits.

An example of asymmetric uplift toward the side of the dome opposite the best developed syncline occurs at Raccoon Bend. Teas and Miller,[5] in their paper on Raccoon Bend, call attention to the fact that the two highest wells in the field are located approximately 3,500 feet east of the center of the structure. Their structure map on the top of the Gutoskey sand shows rather gentle structure on the north-to-west flanks and much steeper structure on the south-to-east flanks of the dome.

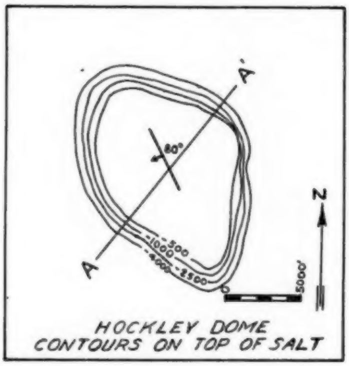


Fig. 12.—Hockley salt dome, Harris County, Texas.

A southwest-northeast profile (AA', Fig. 11) across the Hockley dome illustrates a simple case of the effect of differential uplift. The beds on the southwest flank abut against the dome in a nearly horizontal position but on the northeast flank they are uplifted into an almost vertical position, indicating that the shift and greatest uplift are toward the northeast and that greatest development of the peripheral sink should be toward the southwest.

It is interesting to note that large dark bands may be seen in the white salt extending across the ceiling of the Hockley salt mine. The strike of the bands is north-northwest and south-southeast and the dip approximately 80° WSW. (Fig. 12). The strike of the banding is parallel with the major axis of the dome. This evidence, though it may prove to be local, seems to indicate that most of the salt flowing into

[5] L. P. Teas and C. R. Miller, "Raccoon Bend Oil Field, Austin County, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 12 (December, 1933), pp. 1459–91.

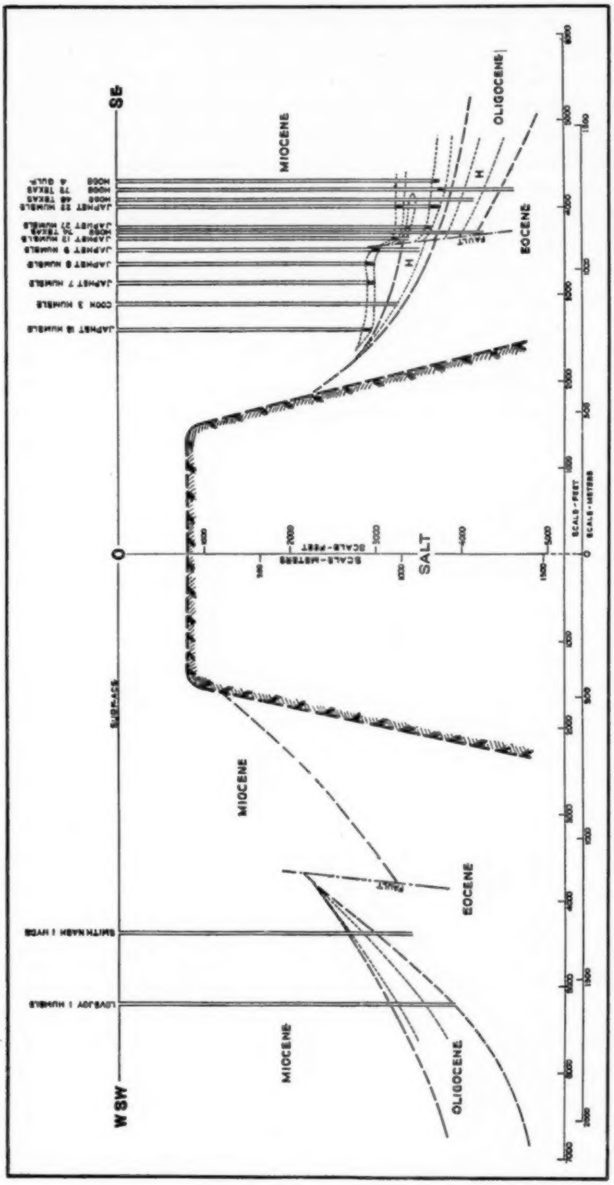


FIG. 13.—Section through West Columbia dome, Brazoria County, Texas. (From D. P. Carlton, "West Columbia Salt Dome and Oil Field, Brazoria County, Texas," *Structure of Typical American Oil Fields*, Vol. II, Amer. Assoc. Petrol. Geol., 1929, pp. 451–69.)

the dome came from a direction at right angles to the major axis of the dome.

Figure 13 illustrates the faulting complications that probably exist around many domes. On the left the downthrown side of the fault is adjacent to the dome, but on the right the downthrown side is farthest away from the salt, indicating tension on the left and compression on the right. Growth of the dome upward and eastward has apparently evacuated a space on the west flank, into which the Eocene

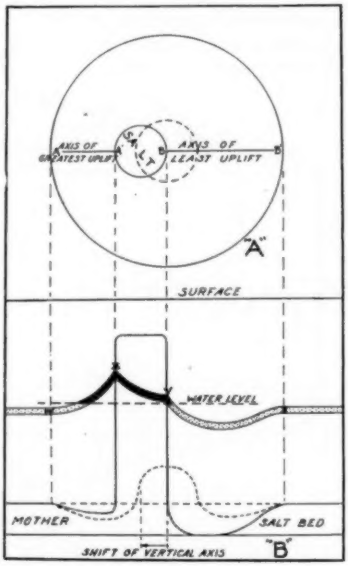


FIG. 14.—Plan and cross section of salt dome whose vertical axis has shifted, showing probable effect on penetrated oil-bearing formation.

and older sediments collapsed. Uplift and compression on the east flank exceeded the competence of the formations resulting in compression faulting and flank-type production approximately $\frac{1}{4}$ mile away from the salt. It seems reasonable to believe that scientific study and exploration of known shallow domes will lead to the discovery of similar structural conditions on many domes where the existence of such structure is not now suspected.

It seems logical, on the basis of the preceding discussion, to state that a dome which has been uplifted with a southerly shift would be

more favorable for oil production than one which has been uplifted with a northerly shift, because such a dome would have its maximum uplift, and minimum peripheral subsidence on the south flank.

Figure 14-A shows the plan of a hypothetical dome in eccentric position with regard to its peripheral sink. The inner dashed circle represents the probable original position of the incipient uplift and the inner solid circle the present position of the top of the salt. The large outer circle represents the circumference of the peripheral sink. The space between the present position of the salt dome and the outer edge of the sink represents not only the actual area of the sink, but is an index of the depth as well (the greater the width of the sink, the greater the depth).

Figure 14-B shows a profile of a salt dome along axis *AA′ BB′* illustrating the probable attitude of a producing formation. *WX* shows the dip from *A* to *A′*; *XY* shows the contact of the formation with salt around the periphery both ways from *A′* to *B*; and *YZ* shows the probable attitude of the formation from *B* to *B′*. The probable location of the oil is shown in solid black, the base of the oil being the bottom-water line. The illustration is, of course, that of an ideal case. In the field these conditions would be complicated by faulting, lensing, erratically shaped sinks, *et cetera.* The faulting may be radial, tangential, or peripheral. The best conditions for accumulation of oil would exist if *A* and *W* are downdip. If *B′* and *Z* were downdip, diversion of the oil by the syncline would be much more probable.

It is believed that this flank of greatest uplift is the most favorable for prolific production. Attention is called to the fact that most of the flank production at many domes is limited to one flank of the dome and other flanks are dry or relatively non-economic.

It is believed that valuable additional information will be accumulated in the coming years, from the wells which will be drilled, which with careful study will enable us to limit future exploration to the possible producing horizons of the respective domes. The possible producing horizons will vary at the different domes depending on geographic location, location and depth of the accompanying sink, and many erratic geologic conditions which are beyond the scope of this article.

SUMMARY

Inspection of the Gulf Coast subsurface map reveals indications of rim synclines on all domes contoured on the McElroy horizon, the general rule being the greater the salt uplift, the greater the syncline. The coastal area, contoured on the *Heterostegina* formation, shows

fainter indications of synclines, indicating that much of the uplifting of the formations by domes and subsidence of the formations into rim synclines took place prior to *Heterostegina* time.

The economic conclusions of the foregoing study are as follows.

1. Overlapping peripheral sinks may be of major economic importance in the future Gulf Coast oil business.

2. Prospecting on a dome known to have a well developed rim syncline on the downdip side is extremely hazardous and, except in cases of rare good fortune, unprofitable.

3. Large shallow domes are most likely to have well developed rim synclines.

4. Extreme caution should be used in prospecting formations older than the Frio on any Gulf Coast dome because of the probability that less and less oil in progressively older formations has ever reached the dome in commercial quantities.

5. High wells, due to the uplift of the dome, may exist outside the peripheral sink of the dome, a condition which is likely to lead the subsurface geologist astray in his search for structure.

6. Peripheral faulting, due to decrease in diameter of the dome with depth, may seal off accumulation of oil from the dome and cause reservoirs to be formed somewhat farther from the dome than the common type of flank reservoir.

NOTE

Subsurface data, recently made available to the writer, indicates that rim synclines are much better developed in the younger formations of the southern coastal zone than was believed at the time of the writing of this paper. Consequently the possibility of discovering residual high type oil fields in this province seems greatly enhanced.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 20, NO. 11 (NOVEMBER, 1936), PP. 1439-1453, 2 FIGS.

SUMMARY DIGEST OF GEOLOGY OF TRINIDAD[1]

H. G. KUGLER[2]
Pointe-a-Pierre, Trinidad, B.W.I.

ABSTRACT

E. Lehner's "Introduction to the Geology of Trinidad" prompted this paper which summarizes the geology and oil possibilities as given by Lehner, and the writer's more recent information which modifies and amplifies that of Lehner.

The discovery of commercial accumulations of oil in eastern Venezuela led to the stratigraphical correlation between Venezuela and Trinidad. Trinidad will always be foremost in the geological literature of the Antilles and northern South America because of its many type localities established by original description of their well preserved Tertiary fossils. Because of the complexity of stratigraphical correlation, geologists should agree to a standard terminology for recognized formations—extraordinarily rapid lateral changes in most beds have been responsible for the abundance of non-indicative nomenclature.

Trinidad is a part of the Caribbean Coastal Range of Venezuela and displays all the structural characteristics of this mountain system.

The discovery of new oil fields in Trinidad is highly probable, but owing to complicated geological conditions information obtained from intensive wildcat drilling should supplement that from geologic mapping. Indications of oil in the Cretaceous of Trinidad are almost as common as those in beds of the same age north of the Guanoco area of eastern Venezuela. With the exception of insignificant production in the Lizard Springs field, no oil has been found in the Cretaceous of Trinidad. No beds older than the Cretaceous have been found in Trinidad.

INTRODUCTION

In 1935, E. Lehner published an introduction to the geology of Trinidad[3] which forms the basis on which this paper is founded.

In 1860, Wall and Sawkins published their fundamentally important report on the geology of Trinidad and this has been augmented by an almost incessant stream of information, mostly of a progressive nature.

The greatly welcomed list of 156 publications appended to Lehner's summary digest of the geology of Trinidad represents a fairly complete account of the known geological literature of the island and Lehner's paper itself represents a noteworthy addition to this list.

A review of the dates of the different publications indicates that a greatly renewed interest in the geology of the island has taken place since 1920 when exploration for oil began to assume vigorous proportions.

[1] Manuscript received, August 8, 1936.

[2] Consulting geologist, Trinidad Leaseholds Ltd.

[3] E. Lehner, "Introduction à la Géologie de Trinidad et Bibliographie Géologique," *Annal. Combust. Liquides* (Paris), No. 4 (1935), pp. 691–730.

Since then, detailed geologic mapping in conjunction with carefully conducted paleontological research work has disclosed many new features of economic importance.

The study of the island's geology received additional impetus from the discovery of commercial accumulations of oil in eastern Venezuela. This led to stratigraphical correlation between the two countries resulting in a good deal of corroborative evidence being obtained. In this connection, it is hardly necessary to add that an accurate knowledge of Trinidad's geology is of vital importance to any valuation of prospects in eastern Venezuela, where the oil-bearing structures are hidden below the Pleistocene and Quaternary cover of the Llanos.

It is, therefore, not surprising that the geological information which has been forthcoming since the time Lehner's paper was submitted to the publishers necessitates some modification or amplification of his views.

STRATIGRAPHY

Trinidad will always occupy a foremost position in the geological literature of the Antilles and the northern part of the South American mainland on account of the many type localities established by the original description of their well preserved Tertiary fossils.

Also, the intricate stratigraphical and structural conditions of the island are frequently examined and discussed by geologists interested in the possibilities of discovering new oil fields.

As far as the complexity of stratigraphical correlation is concerned, the writer is firmly convinced that this will be satisfactorily solved and that this complexity will be reduced to a few conveniently circumscribed formations as soon as sufficient paleontological data are available.

Solution of the problem will be hastened if the geologists at present engaged in geological surveys of the island unanimously agree to a standard terminology for recognized formations and are permitted to coöperate with such an end in view.

By common reference to type localities accurately known from lithological and faunistic standpoints, it is hoped to eliminate the many confusing names for the same formations despite the extraordinary rapid lateral changes in most of the beds, which have hitherto been responsible for this abundance of non-indicative nomenclature.

Whenever possible, formation names should be attributed to localities where macro- and micro-fauna are found to exist together in the same formation contemporaneously deposited.

PRE-CRETACEOUS

The slightly dynamo-metamorphosed rocks of the Northern Range with their conspicuous white quartz veins and the authigenic sericite were, until recently, considered to be older than Cretaceous. Wall and Sawkins appropriately named them "Caribbean series" and Guppy thought that he had found fossils of Paleozoic age in them. As a matter of fact, no beds older than Cretaceous have been found in Trinidad despite the diligent search for fossils in the last 15 years.

It is assumed that the basement rocks of Trinidad are formed by the northward-slanting rim of the Guiana shield with its intensely folded gneisses, schists, and pyrogenetic rocks. These beds of the old Gondwana land, generally considered to be of Archean age, are found in British Guiana almost horizontally overlain by the pink sandstone of the Roraima formation. As no fossils have, as yet, been found in this formation, various authors have called it Permian, Triassic, and even Lower Cretaceous.

The "Old Red series" of Venezuela is probably an equivalent of the Roraima formation.

CRETACEOUS

As far as is known, the Northern Range is composed entirely of rocks of Cretaceous age. Cunningham-Craig was probably the first to advance such a theory by correlating the beds of the backbone of the Central Range with those of the Northern Range by reason of lithological similarity. Since then, Trechmann has mentioned Upper Cretaceous sponges, corals, and other fossil remains from the north coast. In the same zone of calcareous schists, the writer has found lenticular limestone masses with caprinids similar to those of the well known Stack Rock at Pointe-a-Pierre, which is considered to be of Cenomanian age and identical with the Cogollo limestone of Venezuela. Furthermore, the Piparo mud volcano of the Central Range has expelled rock components similar in appearance to the Laventille limestone.

The coarse-grained, almost quartzitic sandstones interbedded with the Cretaceous schists are found to be common components of Tertiary conglomerates and even Quaternary hilltop gravels of southern Trinidad.

Although there would be no hesitation in comparing the sericitic sandy schists and quartzitic sandstones with the Lower Cretaceous Barranquin beds, and the calcareous shales and limestones with the Upper Cretaceous Guanoco (Colon) shales of Venezuela, any attempt

to separate and group these different formations would be a puzzling task. This difficulty is increased by a great deal of conflicting paleontological evidence.

Lower Cretaceous.—In the western prolongation of the limestone belt of Port-of-Spain, Five Islands, Point Gourde, and Gasparee lies the little island of Patos just off the coast of Venezuela.

The limestone of this island contains, in its lower part, subangular pebbles and cobbles of white quartzite and especially of pink sandstone similar to the "Old Red series" of Venezuela. At the present time, this Patos conglomerate may be considered the oldest formation cropping out in or near Trinidad.

More substantial evidence of the presence of Lower Cretaceous is found on the coast at Pointe-a-Pierre where a breccia about 2 feet thick and interbedded with calcareous silts contains *Trigonia caudata, Exogyra sinuata,* and other Cretaceous fossils, known since the survey of Wall and Sawkins.

This intra-formational breccia, commonly known as the "Remanié bed," belongs to the La Carriere formation which, besides the black, sericitic, calcareous silt with mudstone nodules, may include, in other parts of the Island, fissile marlstone with *Didymotis* and even ammonites of Aptian age. The La Carriere formation crops out in several areas along the southern foot of, and inside, the Central Range.

Upper Cretaceous.—The only definitely known Upper Cretaceous rocks, besides those mentioned by Trechmann from the Northern Range, are the rare blocks of calcareous sandstone with *Roudairia, et cetera,* found to be one of the components of the basal conglomerate of the Mount Moriah formation. G. D. Harris places the age of these blocks as Upper Senonian. Whether or not some of the huge blocks of caprinid limestones of the Central Range should also be placed in the Upper Cretaceous will probably be determined in the future. From the information available at present, it seems that an interruption in sedimentation took place between the Lower and Upper Cretaceous eras rather than at the end of Cretaceous time. The arenaceous character of the *Roudairia* beds seems to bear out this assumption, and everywhere in the province of Mexico, Venezuela, and Trinidad, there appears to have been uninterrupted sedimentation from Upper Cretaceous to Lower Eocene time.

EOCENE

The Cretaceo-Eocene transition is represented by the Tarouba formation, the lower part of which is formed by the well known Argiline, a siliceous claystone formation almost barren of fossils. The

less indurated marly shales above the Argiline contain a micro-fauna closely comparable with that of the Velasco shales of Mexico.

The stratigraphical position of the Soldado formation of Midway age with its glauconitic shell beds underlying the silty layers, above which is the *Discocyclina* limestone, is probably between the Tarouba formation and some Middle Eocene marls known as the Pelican rocks, Friendship Quarry, Dunmore Hill, Southern Cunapo Road, and other places in southern and central Trinidad.

These Midway glauconitic shell beds, representing rather shallow-water conditions, are probably indications of zones of limited uplift, whereas in the major part of this depositional period, open-sea conditions were responsible for the deposits of highly foraminiferal marls throughout Lower and Middle Eocene time.

Typical archipelago conditions must have prevailed during Upper Eocene time, which is generally referred to as the Jackson age. The faunas characteristic of this stage are found throughout the West Indies and as far as Peru on the Pacific slope of the Andes. In Trinidad, Jackson deposits are represented by the Mount Moriah formation.

Where the formations of pre-existing uplifts are unconformably overlapped by the Mount Moriah beds, the basal bed of the latter consists of considerable block conglomerate. Such examples are known at the type locality at San Fernando, also at Soldado Rock, and different places in the Central Range. Glauconite, sand, and calcareous silt are superimposed in natural sequence and the cycle ends with marls rich in *Foraminifera*, among which a *Hantkenina* is diagnostically important. The Mount Moriah silt is characterized by colonies of *Lithothamnia*, orbitoids, and echinoids, which have received great attention from paleontologists on account of their stratigraphic value.

The stratigraphical position of the Pointe-a-Pierre formation with its typical variegated silt and shales, flaggy sandstones, and massive grits is still somewhat conjectural. The occasional discovery of a Lower Eocene *Foraminifera*—*Rzehakina*—in the purplish-weathering shales is not conclusive evidence of its age on account of the common occurrence of derived *Foraminifera* in any clastic sediment. The boulder bed at the base of the Pointe-a-Pierre formation is of considerable value as regards the determination of the lower age limit of this formation. This boulder bed contains a very polygenetic assemblage of rocks ranging from Lower Cretaceous to Midway Soldado in age, whereby in one place Argiline and cherts predominate, and in others (Plaisance quarries), *Didymotis* limestone, La Carriere shales,

Lower Cretaceous *Orbitolites* limestone, mudstones with belemnites, or caprinid limestones are found. Some of these blocks measure several hundred cubic feet in volume, clearly demonstrating the erosional activity of the Pointe-a-Pierre sea along cliffs built of Cretaceous and Lower Eocene rocks. Although one must agree with Lehner that there are sound reasons for correlating the basal conglomerate of the Pointe-a-Pierre formation with that of the Mount Moriah formation, the writer is inclined to attribute a slightly older age to the Pointe-a-Pierre conglomerate, on the assumption that during the early part of Upper Eocene time, a muddy shallow sea must have prevailed in the northern part of Trinidad.

This contention is corroborated by conditions in Barbados where the Scotland formation is correlative with the Pointe-a-Pierre formation. In Trinidad, Oligocene *Siphogenerina* beds and probably *Hantkenina* marl of uppermost Eocene age overlap Pointe-a-Pierre beds. In Barbados it has recently been found that the base of the Oceanic series contains a microfauna of almost the same assemblage as is known from the Mount Moriah formation. Thus the Oceanic series may be, in part, Upper Eocene in age. They unconformably overlap the Scotland beds and suggest similar conditions as in Trinidad.

The occurrence of single large blocks of the Mount Moriah and Tarouba formations embedded in *Hantkenina*-bearing marly clay overlying the Mount Moriah silt is sufficient evidence of the island conditions prevailing in late Eocene and early Oligocene time.

OLIGOCENE

In the excellent exposures of the Morne Diablo quarry in southern Trinidad, a *Lithothamnia* reef with its typical association of orbitoids and molluscs is found to interdigitate with *Siphogenerina* marl. This juxtaposition of macro- and micro-faunas would justify the application of the term, "Morne Diablo," to all the deposits in Trinidad of this age. In this case the designation of the Morne Diablo formation is given to a faunal assemblage of close affinities to the Antigue formation of the West Indies or the San Luis formation of Falcon, Venezuela, both of Oligocene age.

The Morne Diablo formation is generally an open-sea deposit of highly foraminiferal marl, but it is replaced by, or merges into, shallow-water deposits such as reef limestones wherever local uplift occurred. The "Bamboo silt" of the Cipero Coast is representative of a slightly silty phase.

Foraminiferal marly clays of great thickness with layers of *Siphogenerina* marls overlying the "Bamboo silt" are known as the

Alley Creek formation. These beds are found throughout Trinidad and eastern Venezuela. That they were also deposited north of the Northern Range is shown by the Bissex Hill marl of Barbados, or the lower Agua Salada formation west of the Tocuyo Valley in northern Venezuela.

Closely allied to the Alley Creek formation, and probably merely contemporaneous facies of different types, are the "Lower Green clays," lower Ste. Croix beds, the pteropod marls of St. Lucia, the Princes Town marls, *et cetera*.

All these deposits are characterized by very rich assemblages of *Foraminifera*, layers of radiolarians and diatomaceous earth, pteropod oozes, and other forms of pelagic life. They almost imperceptibly merge from one facies to the other, and even silty and sandy intercalations are present.

Near the end of Oligocene time, rejuvenation occurred and led to the formation of limestones, for example, those of the Tamana formation. They form fringing reefs all along the backbone of the Central Range (Guaracara-Biche) or in a few isolated patches such as the Ste. Croix quarry at Lothians, the *Amphistegina* marls in wells near the Pitch Lake, or in blocks expelled from the mud volcanoes of the Cedros Peninsula.

It is possible, as Lehner's stratigraphical table indicates, that the Tamana formation and several of the beds of the Alley Creek formation actually belong to the Miocene. The latest results of paleontological study and especially the interdigitation of the *Siphogenerina* marls with the typical Oligocene faunal assemblage of the *Lithothamnia* reef of Morne Diablo have, however, caused the writer to place them at a lower horizon—the Oligocene.

MIOCENE

The Miocene of southern Trinidad apparently begins with a conspicuous conglomerate of white and black cherts overlapping the Alley Creek formation and older beds. This conglomerate forms the base of the Palo Seco formation, a monotonous series of silts with layers of sand, having a total thickness of a few thousand feet. Laterally, this conglomerate may be replaced by sand of a pepper-and-salt appearance with a large number of derived Oligocene *Foraminifera*. The Palo Seco formation is followed by the Cruse-Forest formation of very similar lithologic character, but showing a gradual increase of sand toward the south and upward in the formation. The Miocene deposits of the Naparima area differ from the adjoining area farther south in the replacement of an arenaceous facies, by a conspicuous

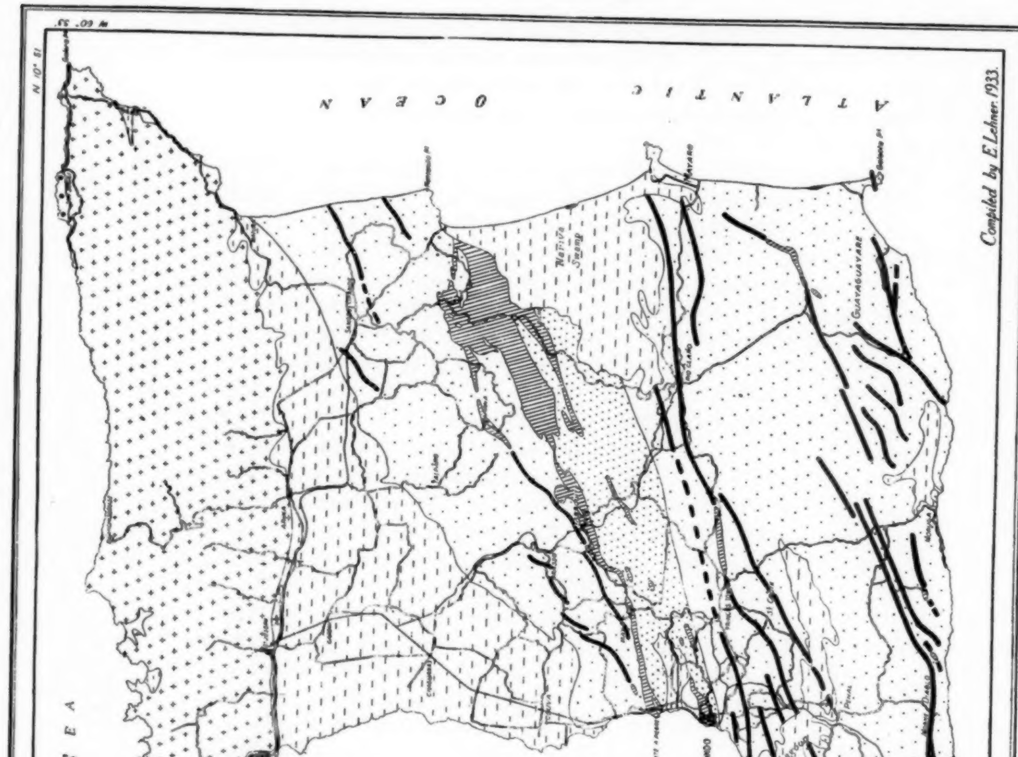


FIG. 1.—Structual map of Trinidad. From E. Lehner, "Geology of Trinidad," *Annal. l'Office Natl. Combustibles Liq.* (Paris), No. 4 (1935).

predominance of clay and marl, indicating more open-sea conditions. These beds contain pure *Orbulina* marl lenses and all these beds together represent the equivalent of the Palo Seco formation.

The Naparima formation with its red-weathering clay, generally called *Cyclammina* clay, is correlative with the Cruse-Forest formation.

On the other hand, along the southern foot of the Central Range, deposits are again found representing shallow-water conditions of a muddy sea into which the grits and sands of the Central Range were laid down. The resulting beds, mottled clays with layers and pockets of unevenly graded sands, have been grouped together under the term Nariva formation or Poonah series. The major part of the Nariva formation is probably equivalent to the Palo Seco and Cruse-Forest formations.

North of the Central Range more open-sea conditions gave rise to the formation of littoral deposits, for example, the Brasso conglomerates with numerous marine shells or the glauconitic Springvale formation and the almost equivalent Brasso formation. The latter is characterized by fossiliferous, dark, marly silts, sandstone, and conglomerates.

PLIOCENE

The upper part of the Cruse-Forest formation shows clear evidence of the gradual depositional upbuilding of the shelf lying north of the Guiana landmass. This process was even more pronounced during the deposition of the Moruga formation. Along the coast from Guayaguayare to Moruga are found several thousand feet of massive sand and silt beds with calcareous, indurated layers which form the hills known as the Southern Range. Whereas these sands were seemingly deposited under marine conditions, a gradual change to brackish-water sediments is represented by the overlying La Brea formation. Well bedded sandy clays with lignitic beds and massive sand are the components of this formation. Where combustion of lignite seams took place, brick red porcellanites were formed which make excellent material for roads in areas where indurated rocks are scarce.

North of the Central Range, the equivalent of the Moruga formation is represented by the upper part of the Manzanilla beds. The equivalent of the La Brea formation is the Comparo formation with the same freshwater faunule, lignites, and porcellanites.

PLEISTOCENE

At the end of Pliocene time, the major orogenic movements which gave rise to the structures controlling the present physiography of

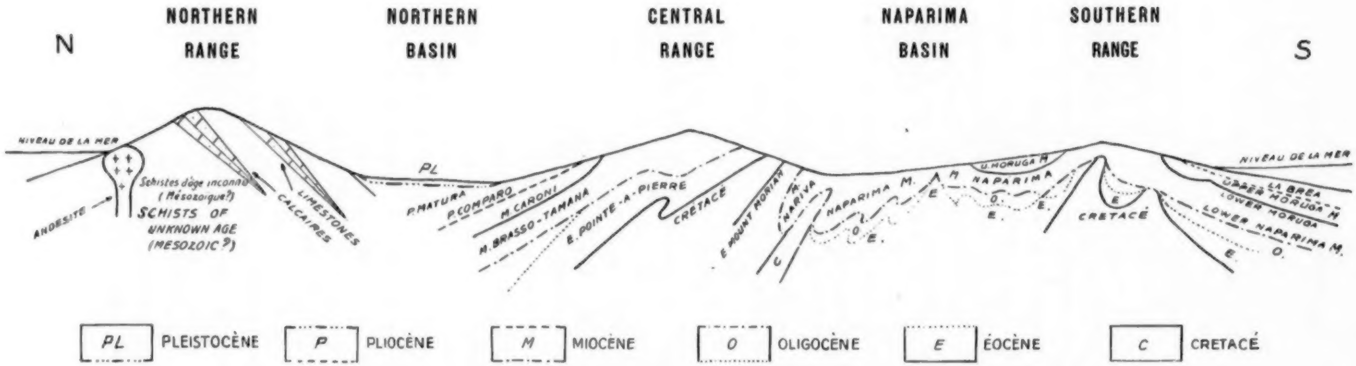


Fig. 2—Schematic north-south section of formations in Trinidad. From E. Lehner, "Geology of Trinidad," *Annal. l'Office Nat. Combustibles Liq.* (Paris), No. 4 (1935).

the island gradually subsided. Again the sea broke into depressions, such as that along the southern foot of the Northern Range, where a marine clay is found to extend from Matura Bay to the Caroni flats. The Matura formation is a shell bed laid down during transgression of this sea. This sea separated southern Trinidad from the Northern Range which at that time was connected with the Venezuelan mainland.

In southern Trinidad, erosion was meanwhile actively wearing all outstanding hills to the same base level of erosion. The derived sediments filled the basins between more resistant formations, thus gradually forming the Naparima peneplain. Plateau gravels, incoherent sands and mottled clays, very similar in appearance to the Llanos deposits of eastern Venezuela, are found not only in southern Trinidad, but also in the Northern Basin, where eventually the Matura formation was overlain by detritus from the Northern and Central ranges. On the remains of such a plateau at Los Bajos, in a former river channel filled with inspissated oil sand, well preserved bones of a *Megatherium* and *Mastodon* were found, thus deciding the age of these later deposits.

Finally, the area of the present Gulf of Paria subsided slightly. The sea broke in from the north and the south and, assisted by strong currents, gradually excavated the shallow basin of the present gulf.

RECENT

Recent formations include present river, lagoon, and beach deposits, and the *ejectamenta* of mud volcanoes. The latter deserve special attention on account of the information which they offer for the elucidation of the composition of the underground formation.

STRUCTURAL CONDITIONS

The writer finds himself substantially in agreement with the structural interpretation as given by Lehner, but the following comments may not be out of place.

Trinidad, being a part of the Caribbean Coastal Range of Venezuela, displays all the characteristics of this mountain system and its southern foreland.

The east-west trend of the Northern Range is deceiving, as the general trend of structural elements is generally found to be northeast-southwest and thus in harmony with the average direction of the pre-Oligocene beds found exposed in the Central Range of Trinidad, Scotland district of Barbados, and all along the Caribbean Coast Range between Trinidad and Puerto Cabello.

This east–west trend is probably the result of rift faulting, evidenced not only by the earthquake regions of Port-of-Spain, Cumana, Caracas, *et cetera*, but also clearly manifested by the longitudinal valleys of the Rio Tuy and Aragua in Venezuela, and especially by the pronounced features of the Peninsula of Paria, Araya, and the Gulf of Cariaco with its eastern extension of lowlands.

It must be left to future investigations to determine to what extent this late Cretaceous and early Cenozoic trend of mountain folding can be connected with Laramide orogeny.

A fan-like structure in the Northern Range is probable if the structural conditions of the Venezuelan Coast Range are considered. East of Valencia, in Trinidad, beds of probable Pliocene age crop out with an inclination of 30° –40° N., and seemingly dip under the older rocks of the Northern Range.

The gypsiferous beds between Port-of-Spain and San Joseph may indicate proximity to formations deposited during arid conditions, for example, the red rocks in the Patos conglomerate. It is even possible to visualize a "decollement" of the entire Cretaceous from the Guiana basement rocks by the aid of this saliferous lubricant.

The exact relations of igneous activity to the general tectonics is not clear, but the intrusions of andesites at Sans Souci may have occurred along rift faults.

The tectonic sketch map (Fig. 1) attached to Lehner's paper conveys a clear picture of the structural conditions in central and southern Trinidad. Although the general strike of the more-or-less intensely folded structures is dominantly northeast and southwest, other trends occur locally, among which are east and west and even north and south segments.

The Point Fortin-Los Bajos structure is of special interest. This is apparently a "hinge fault" with the pivot at the intersection with the Fyzabad structure. The Point Fortin anticline is thrust upon the Irois syncline and the Los Bajos structure upon the Siparia syncline.

Ordinary strike, dip, and oblique faults are abundant in Trinidad. An additional feature which has been overlooked by many, is the evidence of horizontal movement as illustrated by "blatt" faulting.

Almost every type of structure, may be observed, ranging from the normal, elongate dome of southern Trinidad to its highly imbricated equivalent along the thrust belt of the Central Range.

Besides the normal anticlinal oil fields, for example, Lot 1, Fyzabad, Point Fortin, Vessigny, and Los Bajos, there are flank fields, for example, Palo Seco, Barrackpore, Tabaquite, and Guayaguayare.

Tentative Stratigraphical Correlation Table for Trinidad (B.W.I.) by H. G. Kugler Aug. 1936

	NORTHERN RANGE - NORTHERN DEPRESSION	CENTRAL RANGE North Flank	CENTRAL RANGE Central part	CENTRAL RANGE South Flank	NAPARIMA AREA	SW. part of the Island	SOUTHERN RANGE
HOLOCENE	landslides and talus, riverflats, swamp and beach deposits, recent mudflows etc						
PLEISTOCENE unconf	gravel terraces MATURA formn	sand and gravel terraces	sand and gravel terraces	sand and gravel terraces	table-land deposits (Godineau beds)	table-land deposits LLANOS formn.	table-land deposits (Megatherium sands)
PLIOCENE	COMPARO formn. (Talparo beds)	Brasso-Manzanilla facies: COMPARO formn. (Talparo beds)		Nariva facies: NARIVA formn.	Naparima facies: MORUGA beds (Poonah formn)	LA BREA formn.	Moruga facies: Palmiste clay
UPPER MIOCENE unconf		MANZANILLA formn. Springvale beds BRASSO sd + congl.	MANZANILLA formn. Mt Serrat glauconite Los Atajos congl.	NARIVA formn.	NAPARIMA formn. Thyesira marls of Freeman's Bay	Morne l'Enfer beds FOREST-CRUSE formn. PALO SECO formn.	MORUGA formn. FOREST-CRUSE formn. PALO SECO formn. Herrera congl.
MIDDLE AND LOWER MIOCENE		BRASSO clay TAMANA formn. (Machapoorie beds)	BRASSO clay TAMANA formn. (Biche limest)	Green clay TAMANA formn. (Guaracare limest.)	Green clay STE CROIX formn.	Green clay STE CROIX formn. in wells	STE CROIX formn.
OLIGOCENE		ALLEYCREEK formn. (Brasso clay)	ALLEYCREEK formn. (Ditrupa beds) ? Sta. Lucia clay ?	ALLEYCREEK formn. (Williamsville clay) MORNE DIABLO formn. (Cipero or Amusium beds)	ALLEYCREEK formn. (Princestown marl) MORNE DIABLO formn. (Bamboo cl or Lower Ste Croix formn)	ALLEYCREEK formn. in wells MORNE DIABLO formn in wells	ALLEYCREEK formn. MORNE DIABLO formn (limestones of Mejas, Erin etc)
UPPER Jacksonian unconf		MOUNT MORIAH formn	MOUNT MORIAH formn. (Hantkenina marl)	MOUNT MORIAH formn. (Morne Roche beds)	MOUNT MORIAH formn. Mt Moriah congl.	MOUNT MORIAH formn. In wells	MOUNT MORIAH formn
EOCENE		POINTE à PIERRE formn. Plaisance congl.	POINTE à PIERRE formn (Mt. Harris beds)	POINTE à PIERRE formn:			
MIDDLE & LOWER EOCENE Laramide orogeny		undiscriminated marls and mud stones			Retrench and Dunmore Hill marl	Pelican Rock marls	remnants in mud flow
PALEOCENE DANIAN		SOLDADO formn. as remnants TAROUBA formn.	SOLDADO formn. as remnants TAROUBA formn. (Cunapo River argiline)	SOLDADO formn. as remnants TAROUBA formn.	SOLDADO formn. as remnants TAROUBA formn. San Fernando argiline	SOLDADO formn. TAROUBA formn. in mud flow	SOLDADO formn. (Marac limest) TAROUBA formn. (Lizard Spring shale)
MAESTRICHTIAN UPPER SENONIAN		Roudairia beds as remnants			Roudairia beds as remnants		
Laramide orogeny LOWER SENONIAN TURONIAN CENOMANIAN VRACONNIAN ALBIAN APTIAN	CARIBBEAN SERIES: Andesite of Sansscuci. Limest. & calcareous schists of Toco. Graphitic and talcose schists with quartzitic grits. Laventille limestone Patos conglomerate.	remnants of: Didymotis Lst (Aptian) Caprinid Lst (Cenoman) La Carrière sh (Aptian) Belemnite marlst Orbitolites Lst (Aptian) Ammonite limest. Laventille limest.	Amphitriscoelus Lst of Plum Road (? Cenoman) Stackrock with Cenoman. caprinids ? Gault ammonites ? LA CARRIÈRE formn. with Didymotis Lst (Aptian fossils)	remnants of: different cretac. deposits. LA CARRIERE formn.	Boulders of cretac. quartzitic sandstones and cherts mainly in Pleistocene deposits.	reputed find of Didymotis shale in mud flow	Pebbles and boulders of quartzitic sandstones and cherts in congl. younger than Cretaceous

In at least two of these fields, strike faulting is the cause of the accumulation of oil.

OIL INDICATIONS

Apart from the famous Pitch Lake and the numerous mud volcanoes, there are countless showings of gas, oil, asphalt, and waxy deposits south of the Central Range.

Of special interest is the occurrence of pyrobitumen similar to impsonite in Eocene and Cretaceous beds.

The graphite of the calcareous shales of the Northern Range must be considered as representing the metamorphosed remains of bituminous shales similar in age and aspect to the Colon shales of Venezuela or the Viletta shales of Colombia.

Indications of oil in Cretaceous beds of Trinidad are almost as common as those in beds of the same age north of the Guanoco area in eastern Venezuela. However, with the exception of the insignificant production obtained from the Cretaceo-Eocene marls of the Lizard Springs field, no oil has been produced, as yet, from the Cretaceous beds of Trinidad.

AVENUES FOR FUTURE DEVELOPMENT

Lehner clearly and correctly sums up the position in his inference that the future discovery of oil fields in Trinidad is considered highly probable, but that owing to the complicated geological conditions, information from intensive wildcat drilling is indispensable in supplementing information obtained from geologic mapping.

All the simple anticlinal structures of southern Trinidad have obviously been tested or are under exploitation, but other accumulations of oil trapped along sealing faults will undoubtedly be found.

It is the stratigraphic accumulation of oil, however, which offers the best prospect for the discovery of new fields. Therefore, not only must buttress sands be discovered, but changes from sand to clay advantageously situated on structure should be just as diligently sought.

There is such a wealth of evidence in Trinidad in favor of extensive vertical migration, that any reservoir at one time or another connected with an oil-producing formation by open faults or shattered zones, may be of value.

The occurrence of oil in synclinal regions in Trinidad has been established. In addition, it has been found that water can occur updip from oil in the same sand horizon due to selective injection under specific fault conditions.

The Lower Cretaceous La Carriere shale and the Cretaceo-Eocene mudstone beds of the Argiline type are considered outstanding examples of oil source rocks in addition to the bituminous Tertiary marl.

Any reservoir sand younger than these beds may contain oil, and where stratigraphic and structural conditions are such as to insure fairly uniform conditions in a reasonably large area, a new oil field may be discovered.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 20, NO. 11 (NOVEMBER, 1936), PP. 1454-1475, 3 FIGS.

PERMIAN AND PENNSYLVANIAN SEDIMENTS EXPOSED IN CENTRAL AND WEST-CENTRAL OKLAHOMA[1]

DARSIE A. GREEN[2]
Tulsa, Oklahoma

ABSTRACT

The observations here recorded were obtained in connection with structural mapping in 23 counties in central and west-central Oklahoma. The stratigraphic section begins with the Belle City limestone and extends upward to include the Quartermaster formation. In order to avoid lengthy descriptions, detailed columnar sections have been arranged to show the gradations and relative positions of the sediments below the Marlow overlap.

The Vamoosa formation overlaps southward. The continuous limestone which separates the Vamoosa from the Pontotoc terrane is the Deer Creek of the Pawhuska formation. The Grayhorse limestone marks the top of the Vanoss formation across the entire area. The Asher sandstone is a gradational equivalent of the upper Stratford shale. The Pontotoc terrane is 1,350 feet thick in T. 9 N. The top of the Pontotoc is the approximate time equivalent of the Herington limestone of northern Oklahoma. The Permian-Pennsylvanian contact is considered to be at this horizon.

The Wellington and Garber can not be separated south of northern Oklahoma County. In Cleveland County the Garber-Wellington section is 900 feet thick and is 90 per cent sandstone; southward it grades rapidly to a predominance of shale in northern Garvin County. In west-central Garvin County, sandstones equivalent in age to the Garber grade northward into shale.

The Hennessey shale boundaries transgress stratigraphic boundaries. In southern Garvin County the Hennessey-Garber-Wellington section contains no continuous mappable beds or formation contacts. One bed near the top of the Hennessey is mappable in this area.

The Duncan sandstone is a wedge 600 feet thick in the southeastern part of the Anadarko basin, where it has been divided into three local members. The point of this wedge extends northward to Kingfisher County and westward to Kiowa County. No unit comparable with the description of the "Chickasha formation" can be traced.

South from Canadian County and east from Kiowa County, the Blaine and Dog Creek formations lose their identity through gradations. The equivalents of both formations are absent through erosion and subsequent overlap in southern Grady County where the Marlow is in contact with the middle Duncan.

The Marlow unit is given formation rank which agrees with Roger Sawyer's original classification. Columnar sections show the members and beds of this formation. The Rush Springs sandstone is also given formation rank since it has an unconformity at the base and one at the top. Cloud Chief gypsums are local facies of the basal sandstone member of the Quartermaster formation. All the Quartermaster dolomites are limited to this same member and occur irregularly in a section at least 125 feet thick. Any or none of these dolomites may be the equivalent of the Day Creek dolomite of northwestern Oklahoma. The Quartermaster formation has the Doxey shale member in the middle and the Elk City sandstone member at the top.

The two Pennsylvanian limestones previously mentioned and the Blaine gypsum formation are the only markers that can be traced definitely from the Kansas line through central Oklahoma. The remaining 98 per cent of the sediments are largely shoreward gradations. The classifications of these non-marine sediments can not be adjusted to fit the details of divisions made in the marine section on the north.

[1] Read before the Association at Tulsa, March 19, 1936. Manuscript received, September 23, 1936. Published by permission of the chief geologist of The Pure Oil Company.

[2] The Pure Oil Company.

The term "Red-beds" has been avoided since color changes are obviously stratigraphically transgressional or associated with local structure. In the Pennsylvanian sediments the red color is most pronounced in areas having the highest percentage of sandstone. About 75 per cent of the sediments of the entire area are red in color.

INTRODUCTION

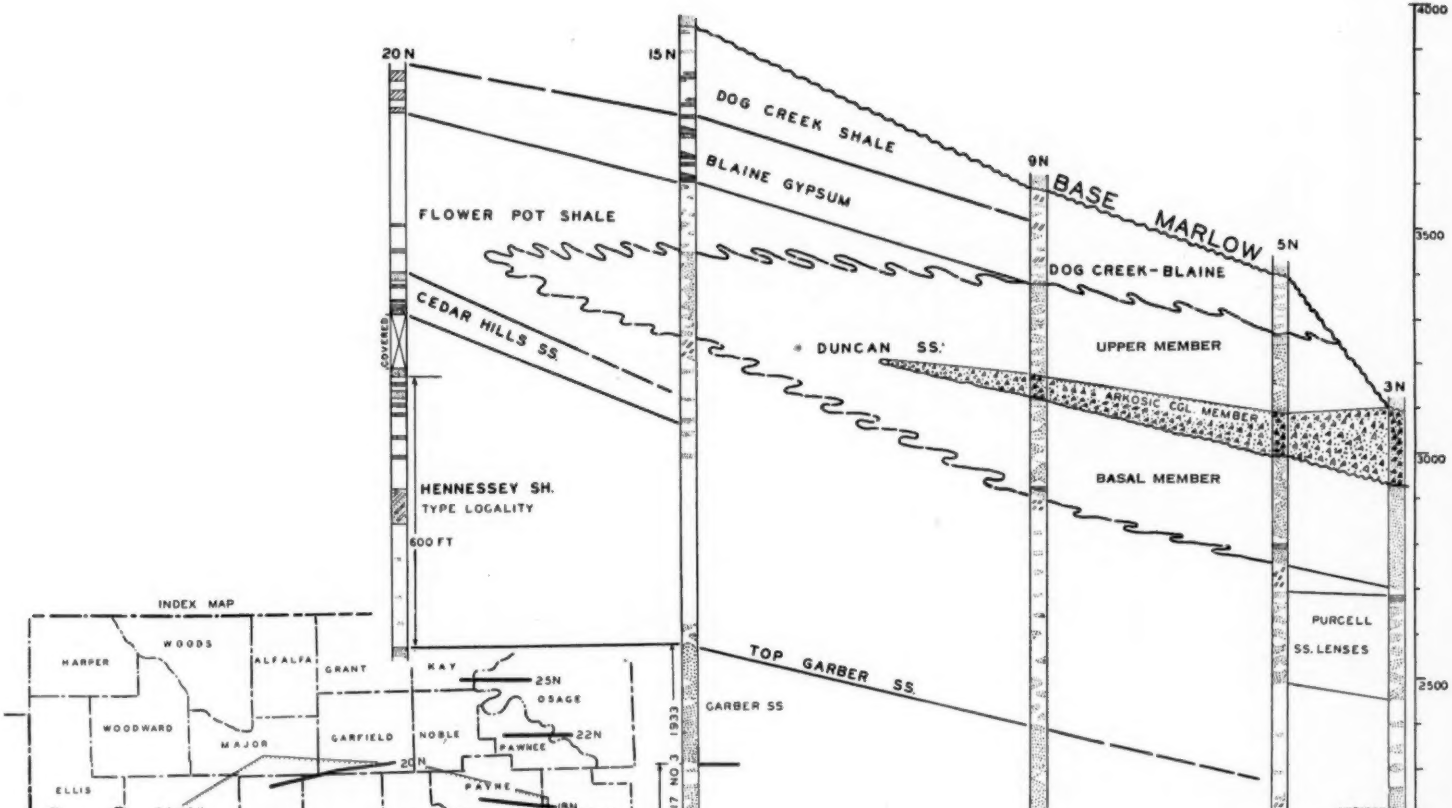
This discussion of the sediments exposed in central and west-central Oklahoma is based on detailed structural mapping. The assistance and coöperation of the numerous Pure Oil Company geologists who have mapped local areas have made it possible for this assemblage of data to be presented.

The geographic extent of the area discussed is shown by the hachured lines on the index map (Fig. 1). The stratigraphic section begins at the Belle City limestone, of Pennsylvanian age, and extends upward to include the Quartermaster formation which is the youngest Permian in Oklahoma. These limits have been extended both upward and downward since the presentation of the paper at the Tulsa meeting in March, 1936.

The sediments of central Oklahoma are primarily non-marine. Sediments below the top of the Pontotoc terrane have been mapped northward and time equivalents have been established between these Pontotoc sediments and the section below the Herington limestone of northern Oklahoma (Fig. 1). These equivalents do not agree with much of the published classification which has been based largely on hasty reconnaissance observations.

Some of the classifications of the sediments above the Pontotoc terrane are even more revolutionary than the discrepancies found in the sediments of Pennsylvanian age. The Marlow overlap reveals geologic history which has hitherto been missed. The classification of the Quartermaster which shows it to include the Cloud Chief gypsum facies may be expected to encounter many protests.

In this central area there are only three definite stratigraphic markers which can be traced into areas outside of Oklahoma. These are the Deer Creek limestone, the Grayhorse limestone, and the Blaine gypsum formation. The remaining 98 per cent of the sediments are discontinuous lithologic units due to unconformities, gradations, lenticular deposition, and chemical alterations. For these reasons it is hazardous to correlate a local clastic unit such as the Garber sandstone or Duncan sandstone wedge with some lithologically similar unit far out beyond the limits of deposition of the local unit. The establishing of approximate time relations is here attempted but no effort is made to extend formation boundaries beyond the gradations



20 N
15 N
9N
5N
3N
4000
3500
3000
2500
2000
DOG CREEK SHALE
BLAINE GYPSUM
BASE MARLOW
FLOWER POT SHALE
DOG CREEK-BLAINE
CEDAR HILLS SS.
DUNCAN SS.
UPPER MEMBER
ARKOSIC CGL. MEMBER
BASAL MEMBER
HENNESSEY SH.
TYPE LOCALITY
600 FT
COVERED
PURCELL
SS. LENSES
TOP GARBER SS.
GARBER SS
ICONIUM SH.
ANTIOCH SS.
GARBER-WELLINGTON
ELLINGTON
AAPG BULL VOL 17 NO 3 1933
INDEX MAP
HARPER
WOODS
ALFALFA
GRANT
KAY
OSAGE
WOODWARD
MAJOR
GARFIELD
NOBLE
PAWNEE
ELLIS
DEWEY
BLAINE
KINGFISHER
LOGAN
PAYNE
CREEK
ROGER MILLS
CUSTER
CANADIAN
OKLAHOMA
LINCOLN
OKFUSKEE
BECKHAM
WASHITA
CLEVELAND
POTT.
25N
22N
20N
18N
15N
12N
9N

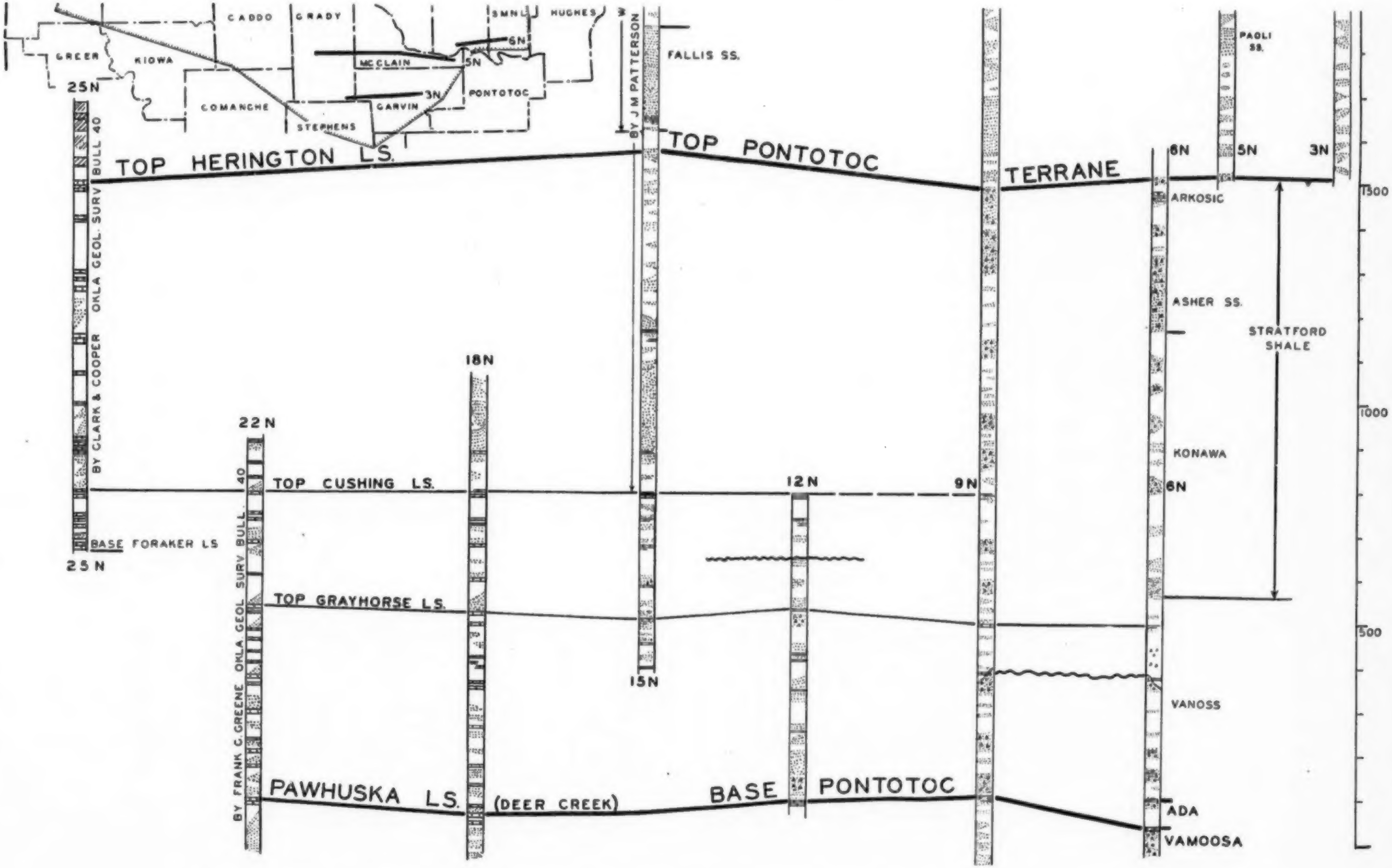


FIG. 1.—Detailed surface sections, showing gradations and relative stratigraphic positions of sediments in central Oklahoma.

in which their identity is obliterated. The purpose of this publication is to give the reader a clear conception of the conditions revealed by the sediments which are exposed within the geographic limits here outlined. It is not an attempt to fit these shoreward wedges and lenses into correlation charts which are applicable to adjoining areas of marine beds.

MAJOR SEDIMENTARY DIVISIONS OF CENTRAL OKLAHOMA

The most logical division of the sedimentary units in central Oklahoma is as follows.

13. Quartermaster formation
12. Rush Springs formation
11. Marlow formation
10. Dog Creek formation
9. Blaine formation
8. Duncan sandstone wedge
7. Hennessy shale
6. Garber-Wellington section

Permian-Pennsylvanian Contact

5. Pontotoc terrane, including all Ada above Deer Creek equivalent
4. Pawhuska limestone (Deer Creek or Lecompton)
3. Vamoosa formation
2. Unclassified shales and sandstones; wedge between Vamoosa and Belle City north of T. 7 N.
1. Belle City limestone

BELLE CITY LIMESTONE

The areal extent of the outcrop of the Belle City limestone is accurately shown on the *Geologic Map of Oklahoma*.[3] In the Stonewall Quadrangle Morgan[4] included two limestone beds and an intervening shale in the Belle City. The lower limestone grades rapidly into sandstone in Seminole County. At the southernmost exposure, Morgan describes the upper Belle City limestone as being only one foot thick. Northward the bed thickens, reaching the maximum of 20 feet at the south line of T. 7 N., R. 7 E. North from here it begins to thin again, being 5–7 feet thick west of Wewoka and less than one foot thick where it finally grades into sandstone in the south part of T. 10 N., R. 8 E. The bed is known to extend westward underground for many miles and it is probable that it extends around the west side of the central sandstone phases in Okfuskee and Creek counties and is represented by the Dewey or Avant limestone west of Sapulpa. This suggested correlation probably could never be checked by either surface or subsurface study.

[3] *U. S. Geol. Survey et al.* (1926).

[4] George D. Morgan, "Geology of Stonewall Quadrangle," *Bur. of Geol. Bull.* 2 (1924), Norman, Oklahoma.

VAMOOSA FORMATION

The Vamoosa formation in the Stonewall Quadrangle has been described by Morgan[5] who gives it an average thickness of 260 feet; 230 feet of sandstone-chert conglomerates and 30 feet of dark shale at the base.

In the area extending 25 miles north from the Stonewall Quadrangle the Vamoosa is a unit of lenticular sandstones, conglomerates, shales, calcareous sandstones, and calcareous conglomerates. The coarsest conglomerates are in the basal 50 feet and the finer conglomerates are in the upper part of the formation. The upper limit of the conglomerates is irregular; in places they extend up to the Pawhuska limestone while short distances away there are no conglomerates in the first 50 feet below the Pawhuska. The formation shows definite effects of having been cut by cross currents during the time of its deposition, the best examples of which may be seen in T. 7 N., R. 6 E.

The first continuous bed above the Vamoosa formation is the Pawhuska limestone which is 65 feet below beds mapped in the Ada formation by Morgan (northeast corner of Sec. 16, T. 6 N., R. 6 E.). The Ada formation was described as having a thickness of about 60 feet in this area; therefore the Pawhuska may be considered as basal Ada. At the north line of the Stonewall Quadrangle the interval from the Pawhuska to the Belle City limestone is 300 feet. As shown by Levorsen[6] this interval increases rapidly toward the north. Contrary to Levorsen's interpretation, the Vamoosa formation does not fill this entire interval as it increases toward the north. In T. 9 N., R. 7 E., the section is as follows.

4. Pawhuska limestone
3. Vamoosa formation, 325 feet
2. Unclassified non-conglomeratic shales and sandstones, 225 feet
1. Belle City limestone

In the southeast quarter of Sec. 11, T. 9 N., R. 7 E., crinoid stems occur in a local hardening of a sandstone 110 feet above the Belle City limestone. At the same position in Sec. 6, T. 9 N., R. 8 E., some fossil wood occurs. This horizon is well below the base of the Vamoosa formation.

The overlapping by the Vamoosa formation may be measured by exposures in Secs. 19 and 30, T. 7 N., R. 7 E., where Vamoosa basal conglomerates rest directly on the Belle City limestone. Thirteen miles northeast these basal Vamoosa conglomerates are 225–250 feet

[5] *Ibid.*

[6] A. I. Levorsen, "Geology of Seminole County," *Oklahoma Geol. Survey Bull. 40*, Vol. 3 (1930), p. 293.

above the Belle City. Due to the grading out of the Belle City limestone and the difficulty in tracing the base of the Vamoosa conglomerates, the effects of this unconformity are not known in the area farther north. The presence of this unconformity adds more uncertainty to correlations of the Belle City limestone with the limestones in northeastern Creek County.

PAWHUSKA LIMESTONE

The bed called Pawhuska limestone in Sec. 16, T. 6 N., R. 6 E., is one of a series of calcareous, sandstone-chert conglomerates. In the south part of T. 7 N., R. 6 E., it is white calcareous conglomerate, grading into thin white limestone in Section 14. It continues as thin limestone northward into T. 8 N., R. 6 E., but grades back to calcareous sandstone-chert conglomerate having a thickness of 15 feet in Sec. 15, T. 8 N., R. 6 E. This is the general characteristic of the bed through T. 9 N., R. 6 E., the thickness varying from 4 to 15 feet. Northward it grades into the well known twin dolomites or limestones west of Paden, in T. 12 N., R. 7 E. From Paden, numerous geologists have traced these beds northward and found them to be the Pawhuska limestone of Buttram's[7] published section at Drumright, which is either the Deer Creek or the Lecompton limestone of the northern Oklahoma section. Unpublished recent work by A. N. Murray of the University of Tulsa shows that it is the Lecompton. In Creek County, the outcrop of this Deer Creek limestone does not follow the line which indicates the top of the Pawhuska formation on the *Geologic Map of Oklahoma*. East of Stroud, the Deer Creek limestone is more than 100 feet below the highest bed included in the Pawhuska formation as indicated on the state map.

PONTOTOC TERRANE

According to Morgan's descriptions, the sediments of the Pontotoc terrane rest on the Ada formation. Since the Pawhuska limestone is the only recognizable Ada bed north of the Stonewall Quadrangle, the base of the Pontotoc, or base of the Vanoss formation, is placed at the top of this Pawhuska limestone in Seminole County. The top of the Stratford shale is the top of the Pontotoc according to the original definition. The distinguishing characteristic of the terrane in the Stonewall Quadrangle is the occurrence of arkosic materials within the conglomerates.

The upper limit of the Pontotoc terrane is more difficult to establish than the base. Beginning west of the Washita River in south

[7] Frank Buttram, "The Cushing Oil and Gas Field, Oklahoma," *Oklahoma Geol. Survey Bull. 18* (1914), p. 10.

ern Garvin County, Sec. 10, T. 1 N., R. 1 E., where more than 100 feet of typical arkosic Stratford shale is exposed, the upper contact of the Stratford shale has been mapped across Garvin and McClain counties and into Pottawatomie County at Wanette. In Secs. 1 and 12, T. 5 N., R. 2 E., and in Sec. 30, T. 6 N., R. 3 E., typical Stratford shale exposures occur. One of the most accessible and convincing of these is at the E. ¼ corner of Sec. 30, T. 6 N., R. 3 E., which is half a mile east of Wanette. Here may be seen a very typical Stratford calcareous arkosic lense which is 20 feet thick. In this locality the upper limit of Pontotoc chert conglomerates is 30 feet above the arkosic lense. There are no chert or arkosic conglomerates within the next 1,500 feet of sediments above these Pontotoc conglomerates.

From Wanette northward the upper limit of the chert conglomerates is at approximately the same stratigraphic position in the next 20 miles, but the arkosic materials fall progressively lower in that direction. Four miles west of Tecumseh, on Oklahoma Highway 41, the top of the chert conglomerates may be seen 150 feet south of the NW. corner of Sec. 17, T. 9 N., R. 3 E. In this area the highest well developed arkosic conglomerates are 600 feet lower in the section and the outcrop is several miles east of Tecumseh. By surface measurements, the conglomerates in Sec. 17, T. 9 N., R. 3 E., are 1,350 feet above the Pawhuska limestone which crops out along the east side of T. 9 N., R. 6 E.

North from Tecumseh the upper limit of the chert conglomerates drops irregularly in the section, the downward transgression amounting to 350 feet within the next 25 miles toward the north. In Pottawatomie County where this transgression begins, at approximately 100 feet above the conglomerates, there occurs the basal contact of a sandstone which is correlated with the Fallis sandstone, described by Joseph Patterson[8] from his type locality in Lincoln County, T. 15 N., R. 2 E. If Patterson's Wellington-Stillwater contact is lowered about 50 feet to the base of the shale below the Fallis sandstone, his Wellington-Stillwater contact becomes the equivalent of the top of the Pontotoc west of Tecumseh in Pottawatomie County. Through this evidence the top of the Pontotoc in Garvin County is correlated as the time equivalent of the Herington limestone in northern Oklahoma.

Vanoss formation.—A limestone which crops out along the east side of the town of Cushing and which is correlated with the Grayhorse limestone of Pawnee County has been traced southward into the north edge of the Stonewall Quadrangle. At Konawa this lime-

[8] Joseph Patterson, "Permian of Logan and Lincoln Counties, Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 3 (March, 1933), pp. 241–53.

stone is at the top of Morgan's[9] Vanoss formation. The base of the Vanoss is at the top of the Pawhuska limestone in Seminole County. The Grayhorse limestone at Konawa is thought to be the same as the limestone which Morgan described northeast of Bebee. The location of this outcrop is in Sec. 28, T. 5 N., R. 5 E.; through apparent misprint the location given is Section 18. By this detailed mapping the Vanoss formation is found to be the time equivalent of the Wabaunsee group and the upper part of the Shawnee group in the marine section of northern Oklahoma and Kansas. This usage of the terms Wabaunsee and Shawnee follows Moore's[10] revised classification.

In the vicinity of Konawa the Vanoss is non-red in color. Northward it contains a much greater percentage of sandstone and is entirely red in color in T. 12 N. Still farther north the red color again disappears as the formation grades into marine sediments.

Konawa and Asher formations.—The exposure of Stratford shale at Wanette makes a radical change in the interpretation of the Pontotoc and moves the contact 8 miles west of that established at Asher. It causes the Asher sandstone to be included in the Pontotoc terrane and makes the Konawa and Asher formations gradational equivalents of the Stratford shale. Close examinations of the Asher sandstone along the highway between Asher and Wanette and of the sediments mapped as Konawa by Morgan south of the Canadian River and northwest from Chism have shown that the sections are identical in characteristics. This gradation from dark calcareous shales to red sandstones in a direction away from the Arbuckle Mountains is quite in accord with the northward gradations of the Belle City, DeNay, and Sasakwa limestones which occur lower in the section. The evidence is rather conclusive that the sandstones of Pontotoc age in Seminole, Pottawatomie, and Lincoln counties were derived from a source other than the Arbuckle Mountains. Both toward the north and toward the south these sandstones grade into calcareous shales (Fig. 1).

PERMIAN-PENNSYLVANIAN CONTACT

The original Permian-Pennsylvanian contact established in the Stonewall Quadrangle is about 150 feet above the Grayhorse limestone at Bebee. By tracing the limestone 80 miles north, this Bebee contact is found about 100 feet below the base of the Foraker limestone, which is one of the many selections paleontologists have pro-

[9] George D. Morgan, *op. cit.*

[10] Raymond C. Moore, "Stratigraphic Classification of the Pennsylvanian Rocks of Kansas," *Univ. Kansas Bull. 22* (August, 1936), pp. 48–49.

posed for the contact in northern Oklahoma. In southern Lincoln County there is a local unconformity nearly at the same position. This unconformity is of such magnitude in T. 14 N., R. 5 E., that it was found impossible to contour the Cushing limestone and the Grayhorse limestone on a common datum. This, however, is only one of the many local unconformities found in sediments of Pontotoc age. Between Seminole and Earlsboro the greatest unconformity is found 100 feet below the Grayhorse limestone, though the one in Lincoln County is 150 feet above the Grayhorse limestone. These conditions indicate that local unconformity within the Pontotoc is no criterion on which to establish the Permian-Pennsylvanian contact.

Based on lithologic breaks, there appear to be only two logical positions for the contact: at the base of the Pontotoc, or at the top of the Pontotoc. Robert Dott[11] has well suggested the top of the Pontotoc for the contact in Garvin County. At the surface in Kansas and northern Oklahoma and in all western Oklahoma subsurface, the most abrupt break in the entire section is certainly at the Herington limestone. In subsurface the great westward thickening above the Pawhuska limestone does not occur between the Pawhuska and the Herington (Fig. 2), but it does occur within the Garber-Wellington section above the Herington. If a definite lithologic break may take preference over indefinite paleontologic evidence, the top of the Herington limestone appears to be the logical Permian-Pennsylvanian contact. As already shown, this is at the top of the Pontotoc terrane in central Oklahoma (Fig. 1).

GARBER-WELLINGTON SECTION

In Logan County, Joseph Patterson was able to separate the Garber sandstone from the lower section by use of his Iconium shale. Southward from Logan County the section becomes more sandy and the Iconium shale contacts are lost, leaving in central Cleveland County 900 feet of section between the Pontotoc and the top of the Garber which can not be divided. In T. 9 N., this section is 90 per cent sandstone and contains no chert conglomerates here or anywhere farther south.

South from T. 9 N., the Garber-Wellington section grades into a section predominantly shale in T. 4 N. This southward gradation is much more rapid than that toward the north. At Paoli the highest Garber type sandstone is approximately 400 feet lower in the stratigraphic section than the top of the Garber sandstone east of Norman.

[11] Robert H. Dott, "Lower Permian Correlations in Cleveland, McClain, and Garvin Counties, Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 16, No. 2 (February, 1932), pp. 119–34.

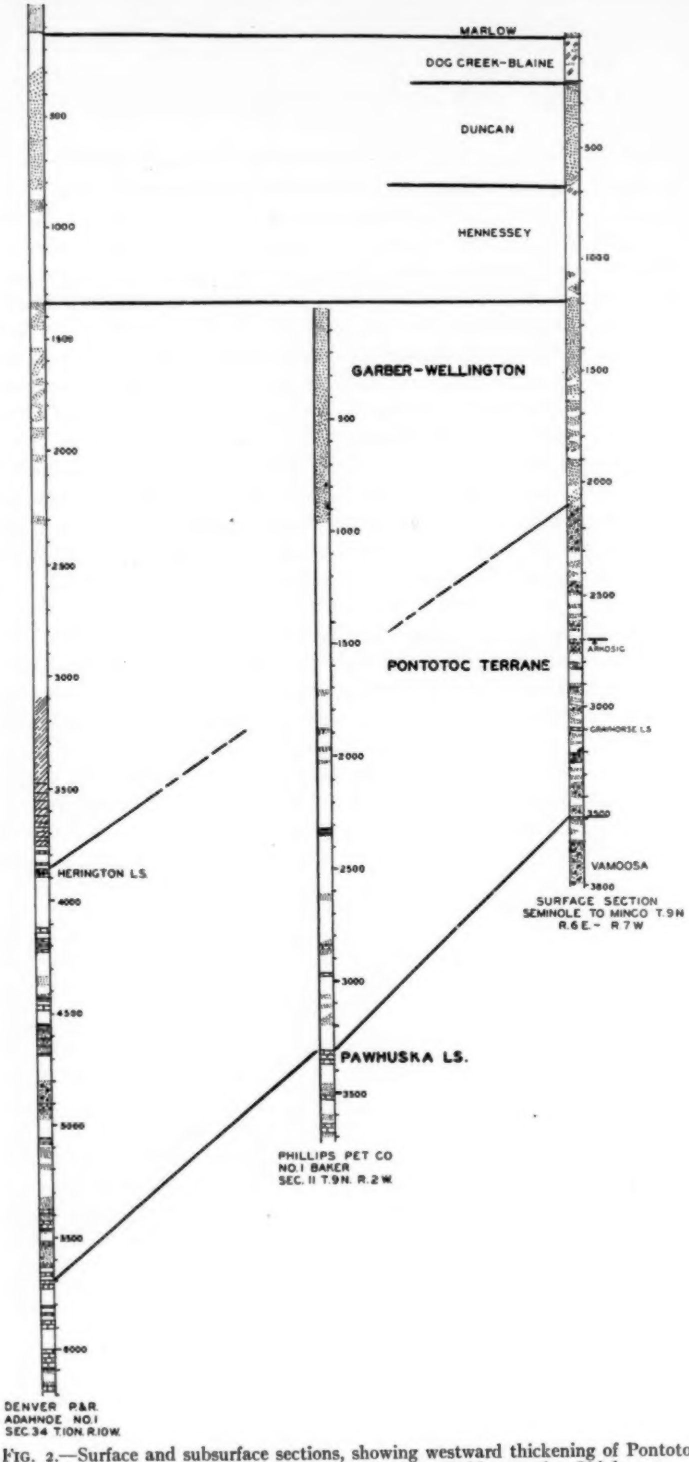


FIG. 2.—Surface and subsurface sections, showing westward thickening of Pontotoc and Garber-Wellington sections from Seminole to Caddo counties, Oklahoma.

The shale into which this upper Garber sandstone has graded is well exposed along the highway between Paoli and Wayne. Between Paoli and the top of the Pontotoc shale on the east, T. 4 N., R. 1 E., the lower part of the Garber-Wellington section is largely shale with many irregular sandstone lenses. Many of these sandstone lenses are of the shoestring type, some not more than 50 feet wide. Some of these lenses are copper-stained to the extent that they have been prospected for ore. Others are mineralized at the base by various other minerals.

South of the Washita River the upper part of the Garber-Wellington section again contains thick sandstones, as at Antioch, in T. 3 N., R. 2 W. These Antioch sandstones grade northward into the shale of the Paoli area, thus indicating that these sandstones did not come from the same direction as the Garber of Cleveland County. Between the Antioch sandstones and the Pontotoc on the east the lower section is similar to that east of Paoli, the sandstones being very lenticular.

Barite rosettes occur at many horizons, but are best developed in the upper part of the Garber-Wellington section in Cleveland County. They have been found down in the Pontotoc near Tecumseh and up in the Duncan sandstone in Sec. 35, T. 6 N., R. 6 W. Pseudo-conglomerates, geodes, and geoidal limestone concretions are common, but are not horizon markers. The occurrence of these barite rosettes, geodes, *et cetera*, may best be explained as the results of percolating waters and mineralization long after deposition.

HENNESSEY SHALE

As shown by the sections (Fig. 1), the Hennessey shale at the type locality does not have the same boundaries as the Hennessey shale in Cleveland County. In central Oklahoma, formation boundaries must necessarily follow lithologic contacts which are gradational both vertically and laterally. These formation contacts transgress lines of time. Areal maps of these formation lines may be misleading in regard to structural interpretation. One of the most common mistakes is caused by the assumption that timber lines follow true stratigraphic lines.

Purcell sandstone lenses.—In the vicinity of Purcell the upper 250 feet of the Hennessey is filled with sandstone lenses, the most prominent of which may be seen in the river bluff just north of the town. In this zone the sandstones are highly lenticular and are cross-bedded, making attempts to map within the zone very discouraging. The lower part of this zone forms a topographic ridge which can be followed

from Purcell to the Table Mountain area in Garvin County. At the Table Mountains, T. 3 N., R. 3 W., the top of the zone is capped by a well stratified, bench-forming bed which can be followed for many miles west and southwest. At Purcell the zone of lenses is 230 feet thick and the base is 150 feet above the Garber sandstone. On the south side of the Washita River, in the area southwest of Maysville, a good shale section 160 feet thick lies between the base of the Purcell lenses and the Antioch sandstone. At the north line of T. 2 N., R. 2 W., this shale section becomes sandy and farther south the division lines are lost. In this south area the section from the top of the Purcell zone down to the Stratford shale is one of extreme lenticularity in which beds or groups of beds can not be mapped with accuracy. In Ts. 1 and 2 N., there is no traceable continuous lithologic break between the Garber-Wellington and the Hennessey sections. This Hennessey-Wellington section in southwestern Garvin County is the ideal place in which to drop the nomenclature applied to the north.

The clastic sediments in western Carter County and in Stephens County between the Duncan sandstone and the Pontotoc are entirely different from sediments of the same age in Cleveland County. The sandstones exposed over the County Line oil pool and over the Velma anticline are commonly referred to as Garber. Examination of these sandstones shows that they contain a great amount of chert and arkosic conglomerates which indicates a source different from that of the Garber. The conglomerates are also different from the Pontotoc which Birk[12] has described at the west end of the Arbuckle Mountains.

An attempt to connect these sandstones with the Garber of Cleveland County by means of subsurface will show both grading into shale as they are carried under the east end of the Anadarko basin.

These arkosic sandstones of the southern area are often erroneously interpreted as Pontotoc conglomerates when found in well cuttings.

DUNCAN SANDSTONE

The Duncan sandstone is a wedge which, if it were not eroded and overlapped, would have a total thickness of 600 feet in the northeast corner of Stephens County. In directions north or west, the Duncan sandstone grades irregularly into the Flower Pot shale. These gradations are nearly equal along the top and bottom of the formation, leaving the central part of the sandstone at the points of the wedge. The north point of the wedge is in Kingfisher County and the

[12] Ralph A. Birk, "The Extension of a Portion of the Pontotoc Series Around the Western End of the Arbuckle Mountains," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 9, No. 6 (September, 1925), p. 985.

west point is in Kiowa County. Other wedges come into the Flower Pot shale from the west, but they are in no way connected with the Duncan deposits.

The term "Chickasha formation" is well established in the literature, but no unit comparable with the Chickasha as described[13] at its type locality can be traced. Since this condition exists, the Chickasha formation has no place in this classification.

The base of the Duncan wedge is at approximately the same stratigraphic horizon extending from the Cruce anticline in Stephens County, through Garvin and McClain counties, to the South Canadian River. The lithologic contact in the river bluffs in T. 10 N., R. 4 W., is less than 100 feet higher stratigraphically than the base of the Duncan in the Table Mountain area, T. 2 N., R. 3 W. Northward from the river the gradation is much more rapid, as indicated by the sections (Fig. 1). The top of the Duncan follows an approximate stratigraphic line from Ninnekah to the vicinity of Minco, in Grady County. This contact is sharp in the vicinity of the town of Pocasset and is well exposed just east of the airport south of Chickasha. The top of the Duncan, like the base, has its rapid gradations north of the South Canadian River.

The thick end of the Duncan wedge has been divided into three members. These divisions are purely local and should not be correlated with sediments found in other states.

Basal member.—This member is at the base of the Duncan sandstone and has a maximum thickness of 250 feet. It is composed almost entirely of sandstone. No conglomerates occur in this member.

Arkosic conglomerate member.—This member has a maximum thickness of 150 feet. It has its greatest thickness and arkosic content in the area southeast of the Knox oil pool, Ts. 2–3 N., R. 5 W.

By referring to Figure 1 it is seen that the arkosic conglomerate member forms a wedge within the Duncan wedge. The point of this inner wedge is in T. 11 N., and north of this point no divisions can be made in the Duncan sandstone. In Stephens and southern Grady counties this member is unconformable with the basal member.

Upper member.—This member has its best development from Chickasha to Middleburg in Grady County. It is composed of sandstones, shales, and every gradation between the two materials. A great amount of the muddy sandstones is calcareous and harder than the adjacent materials. This same type of calcareous material is found associated with the red sandstones from the lower Pontotoc to the

[13] Clyde M. Becker, "Geology of Grady County," *Oklahoma Geol. Survey Bull. 40*, Vol. 2 (1927), p. 112.

Duncan. There is much more material of this type in the upper member of the Duncan sandstone than in any other unit of the central Oklahoma sediments. This member has a maximum thickness of 210 feet. North of the South Canadian River it can not be separated from the lower part of the Duncan wedge.

FLOWER POT SHALE

The position of the Flower Pot shale is occupied by sandstones in the greater part of this central area. The gradation which is shown by the columnar sections between Ts. 5 and 20 N. is very similar to the gradation in a westward direction from Grady County to central Kiowa County.

BLAINE FORMATION

An accurate description of the Blaine formation in northwestern Oklahoma has been published by Noel Evans,[14] who assigned names to four gypsum beds in the formation. Northwest of El Reno in Canadian County a fifth gypsum bed, the Alabaster, is well developed between the Medicine Lodge and Shimer beds. Here the five gypsum beds are interstratified with red shales forming a Blaine section which in T. 14 N., R. 9 W., measures approximately 125 feet from the base of the Medicine Lodge to the top of the fifth gypsum bed. The gypsum beds grade out of the section southeastward. The thicknesses of the gypsum beds here are:

	Feet
5. Haskew	0-4
4. Lovedale	1-8
3. Shimer	1-13
2. Alabaster	3
1. Medicine Lodge	4-7

Evans' sections show thin dolomites at the base of the Lovedale and at the base of the Shimer members. Far south of the disappearance of the gypsums these dolomites form excellent markers for structural mapping in Canadian County. By tracing these beds the conclusion is reached that the base of the Medicine Lodge is the approximate top of the Duncan sandstone at Minco in Grady County. From Minco southward the Blaine formation loses its identity through complete gradation. Across the axis of the Anadarko basin, in the vicinity of Mountain View in northeastern Kiowa County, the two dolomites reoccur separated by the same interval as in Canadian County. East of Mountain View they grade out of the section, but westward they are continuous through Washita, Beckham, and into Greer counties. As these dolomites are traced westward from Mountain View the

[14] Noel Evans, "Stratigraphy of Permian Beds of Northwestern Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15, No. 4 (April, 1931), pp. 405-439.

Blaine gypsum beds reoccur, each bed thickening toward the west so that in Greer County the Blaine section is very similar to that described for northwestern Oklahoma, the uppermost gypsum beds being slightly higher than the highest gypsum beds exposed along the Blaine outcrops of the northern area.

DOG CREEK SHALE

In areas where the Blaine formation can be identified, the Dog Creek shale lies between it and the Marlow formation. At Mountain View the Dog Creek shale is approximately 150 feet thick. In Canadian County it is more than 200 feet thick and contains several continuous thin dolomites in the basal 50 feet. In southern Grady County the Dog Creek shale and the gradational equivalents of the Blaine formation are absent due to erosion and subsequent overlap by the Marlow formation. In some localities the Dog Creek shale shows definite local thinning over the crests of pre-Marlow folds, a condition that Evans did not find in northwestern Oklahoma.

MARLOW FORMATION AND OVERLAP

The Marlow formation was first recognized by Roger Sawyer,[15] who described it and published an accurate map of its outcrop in 1924. However, Sawyer's work was not recognized in the making of the *Geologic Map of Oklahoma* which was published in 1926. Publications of the Oklahoma Geological Survey of even later dates split the Marlow formation between the Whitehorse, Dog Creek, and Blaine formations. Very recently a road log covering a field conference of the Ardmore Geological Society placed the Marlow at its type locality in the Blaine formation.

According to Sawyer,

> . . . the Marlow formation . . . consists of brick-red shales and even-bedded brick-red sandstones with bands of fine white sand and sandy gypsums. The entire formation is gypsiferous, many of the shales containing veins of satin-spar and the sandstones more or less gypsum. A thin layer of almost pure gypsum about 1 foot thick is found at the top of this formation. The thickness of the Marlow formation is about 120 feet.

From detailed work in 9 counties the Marlow formation has been found to be a definite formation which agrees very closely with Sawyer's description. At Verden in Grady County a detailed section of the Marlow was measured. Members and individual beds of this section can be recognized all over that part of the Anadarko basin which lies south and east of the town of Anadarko. North from Ana-

[15] Roger Sawyer, "Areal Geology of a Part of Southwestern Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8 (1924), p. 314.

darko the shales grade into sandstones and the formation becomes one mass of sandstone with thin dolomites in the upper part. At Greenfield, in Blaine County, there are no shales in the Marlow formation. The failure to recognize this northward sandstone gradation caused Noel Evans[16] a great amount of trouble in his attempt to identify the Marlow formation in northwestern Oklahoma (Fig. 3).

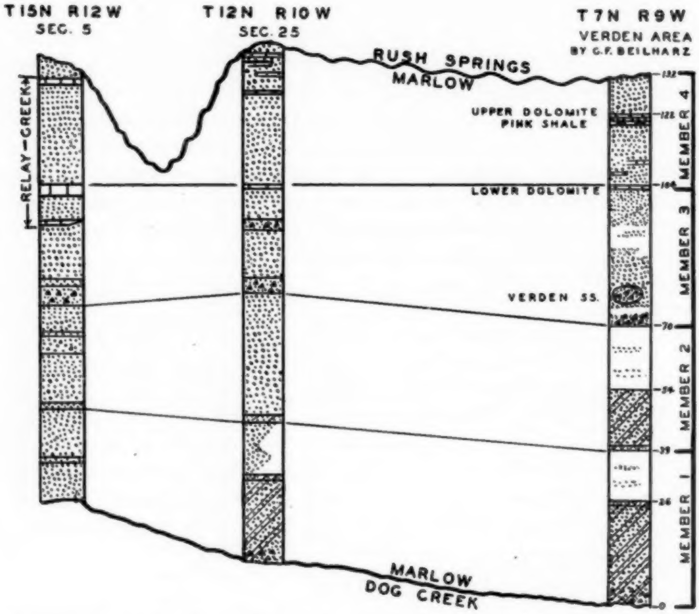


FIG. 3.—Detailed sections of Marlow formation, showing four members in south area and increase in percentage of sandstone and loss of gypsum in north area.

As the formation becomes more sandy it becomes less gypsiferous, thus indicating that the shore of the Marlow sea was on the northwest. In the southeast part of the Anadarko basin the silty nature of the Marlow sands together with the gypsum content of both sands and shales causes a very abrupt change in lithologic character at the contact with lower sediments.

The base of the Marlow is definitely an overlapping contact as shown by the sections in Figure 1. The evidence of this unconformity is more easily recognized along the south side of the basin than on the

[16] Noel Evans, *op. cit.*, p. 419.

north side. It is thought that the major periods of folding and rejuvenations of old folds preceded the Marlow overlap. However, such folds as Cement and the Chickasha gas structure are definite post-Marlow rejuvenations.

The zone of dolomites in the upper member of the formation is continuous throughout the area, but not uniform in characteristics. In most of the area there are only two thin dolomites which occur at intervals ranging from 14 to 20 feet. It is not uncommon for one or both to grade locally into gypsums. The highest development of dolomites in this member is in a somewhat circular area in the vicinity of Greenfield, Hydro, Geary, and Calumet. In this area there are three or more dolomites, some of which have a thickness of 5–6 feet. This area of unusual development of dolomites is the type locality where Evans has applied the name Relay Creek dolomites. Up the Canadian River at the highway bridge east of Thomas in Custer County, the two thin dolomites, with the characteristic band of "Pink shale" one foot below the upper bed, present a section identical with that found in southern Grady County.

Careful study has shown that the dolomites do not mark the top of the Marlow formation. Along the highway east of Anadarko and again in a road cut of U. S. Highway 66 east of the new Bridgeport bridge, a change from Marlow to Rush Springs sediments can be seen along wavy lines 8–10 feet above the upper Relay Creek dolomite. This wavy contact represents a slight unconformity. The maximum relief along this unconformity has been found to be as much as 30 feet.

A phenomenon of the Marlow formation is the occurrence of the so-called "Verden channel sandstone." Some of the outcrops of this deposit are shown on the *Geologic Map of Oklahoma*. Field work has shown that this deposit is limited to one member of the Marlow and that materials similar to those in the prominent exposures are found within this member in widespread areas.

N. W. Bass of the United States Geological Survey has recently made a study of these Verden sandstones and is now preparing to publish the results of his study.[17]

RUSH SPRINGS SANDSTONE

In the southeast part of the Anadarko basin the Rush Springs sandstone formation has been well described as the "Whitehorse sandstone" by Reeves.[18] Here the Rush Springs is a mass of cross-

[17] N. W. Bass, "Origin of Verden Sandstone of Oklahoma," Manuscript; to appear in an early number of the *Bulletin*.

[18] Frank Reeves, "Geology of the Cement Oil Field, Caddo County, Oklahoma," *U. S. Geol. Survey Bull. 726-B* (1921).

bedded sandstone which has a thickness of 160-300 feet, according to the amount of pre-Quartermaster erosion. Deep in the basin where the formation has not been subjected to erosion the Rush Springs sandstone has a thickness of approximately 350 feet as indicated by the sample log of a well drilled in Sec. 23, T. 9 N., R. 17 W. In the vicinity of Weatherford the Rush Springs sandstone has a dolomite-anhydrite bed near the top. This bed was described and correlated with the Day Creek dolomite by Noel Evans[19] in 1928.

In a later publication Evans[20] described this bed as being in the upper part of the Rush Springs sandstone and gave it the name Weatherford dolomite. All the geologists who have worked in the Weatherford area agree with the revised classification.

From the town of Weatherford north and west through Custer County the Weatherford dolomite horizon occurs as a gypsum bed 3-5 feet thick, excepting a few local patches in the vicinity of Arapaho where it is a thin dolomite. One mile south of Weatherford it occurs as a thin red dolomite and continues as such to Sec. 2, T. 9 N., R. 14 W. From this point to T. 8 N., R. 16 W., the bed occurs as anhydrite usually at the base of a gypsum bed. In T. 8 N., Rs. 17 and 18 W., it again occurs as a thin dolomite changing back to anhydrite and gypsum in Sec. 15, T. 8 N., R. 19 W., which is one mile west of Sentinel in Washita County. From Sentinel westward the few exposures are anhydrite and gypsum.

In the vicinity of Alfalfa, exposures in Secs. 13 and 26, T. 9 N., R. 14. W., show the Weatherford to be absent through non-deposition, indicating a grading-out in a southeast direction.

From Weatherford south through eastern Washita County there is a variable section of Rush Springs sandstone between the Weatherford dolomite horizon and the gypsum deposits which are commonly classified as Cloud Chief gypsum. At the town of Cowden this section is 4 feet thick; 6 miles southwest it is 40 feet. Like variations occur in the vicinity of Weatherford and near Custer City. This variation is in part due to the lenticularity of the gypsums, but the principal factor is unconformity. This unconformity may be only local to certain areas in Washita and Custer counties, but its magnitude increases southeast in Caddo and Grady counties.

This unconformity was recognized by Evans and described in detail in his first publication. The question here raised concerns the relative position of this unconformity and the Cloud Chief gypsums.

[19] Noel Evans, "Stratigraphy of the Weatherford Area, Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 12, No. 7 (July, 1928), p. 708.

[20] ———, "Stratigraphy of Permian Beds of Northwestern Oklahoma," *ibid.*, Vol. 15, No. 4 (April, 1931), p. 421.

Evans placed the unconformity above the Cloud Chief but evidence in the outcrops shows it to be below the Cloud Chief gypsums. For this reason it seems logical to group the Cloud Chief member with the Quartermaster rather than to associate it with the Rush Springs to form the "Whitehorse formation."

Where the Weatherford dolomite occurs the first 50 feet of sandstone below it is well stratified, which is in contrast to the cross-bedding below this 50-foot section. In the areas east of the Weatherford dolomite escarpment, where the evidence of unconformity has been so clearly pointed out by Evans, the Quartermaster dolomites cut well down into the cross-bedded Rush Springs. Where Cloud Chief gypsum occurs in areas southeast, the evidence is quite clear that the gypsum also rests on the eroded surface of highly cross-bedded Rush Springs sandstone.

QUARTERMASTER FORMATION

Based on examinations which have been limited to the exposures in Custer, Washita, Beckham, Caddo, and Grady counties, it appears logical to class the sediments above the last-mentioned unconformity as belonging to the Quartermaster formation. This formation can be divided into the following members:

3. Elk City sandstone
2. Doxey shale
1. Cloud Chief (sandstone, gypsum and dolomite facies)

Cloud Chief member.—Any impression that the Cloud Chief is a continuous gypsum deposit approximately 100 feet thick is erroneous. The stratigraphic section in which the gypsums at Cloud Chief are developed is predominantly a sandstone section when considered in a large area. This sandstone section, in which the gypsum facies occur as lenses, has a maximum thickness of 300 feet as shown by the sample log of a well drilled south of Cordell, in Sec. 23, T. 9 N., R. 17 W. At the type locality the basal 100 feet is solid gypsum and the next 50 feet lenticular gypsums in sandstone.

Northwest of Clinton, Sec. 11, T. 12 N., R. 18 W., the contact between the Cloud Chief sandstone member and the overlying Doxey shale is one of irregular gradation. Along this gradational contact occurs a zone of selenite veins. Four miles north, and approximately 250 feet lower stratigraphically, the Weatherford dolomite horizon crops out as gypsum. This 250 feet of Cloud Chief here contains no thick gypsums. The absence of gypsums in this area is substantiated by the log of a well drilled in Sec. 21, T. 11 N., R. 19 W.

The greatest problem in this Cloud Chief member is the occurrence of the Quartermaster dolomites. The relative positions of these

dolomites and the gypsum lenses in many places suggest chemical alteration from gypsum to dolomite. Attention is directed to the calcareous deposits which cap the hills east of the town of Cement and to similar deposits on the Caddo Buttes east of Weatherford. These suggest that they are the resultants of chemical alterations of Cloud Chief gypsums. The Quartermaster dolomites within the Cloud Chief member in the area between Weatherford and Clinton offer a field for intensive study. At the S. ¼ corner of Sec. 17, T. 12 N., R. 15 W., a section of 70 feet of gypsum is exposed. By following a creek westward through Secs. 17 and 18 into the N. ½ of Sec. 24, T. 12 N., R. 16 W., the impression is formed that this gypsum section has graded into one of hardened siltstone which is irregularly cut by numerous white dolomites. The top of a hardened hill in Section 24 is 125 feet above the Weatherford dolomite which crops out in Bear Creek along the west side of the same section. The top of the hill is capped by dolomite and several irregular dolomites are exposed between the top and base of this hill. This and many similar exposures indicate that the Cloud Chief gypsum facies and the Quartermaster dolomites are in the same stratigraphic horizon. Which of these dolomites, if any, is the equivalent of the Day Creek dolomite of northwestern Oklahoma is an open question.

Doxey shale.—As already mentioned the Cloud Chief sandstone member grades upward into the Doxey shale. The nomenclature of Doxey shale and Elk City sandstone is thought to have been used first by H. L. Griley (Twin State Oil Company), who may well be considered as an authority on these members.

The Doxey shale is 160–200 feet thick in Washita and Beckham counties. The upper contact is irregular due to the lenticularity of the first deposits of the Elk City sandstone. Near the middle of the Doxey there are several bench-forming beds of siltstone. These beds clearly show the slumping which is so prevalent in the Quartermaster formation.

Elk City sandstone.—The Elk City sandstone is well exposed in the SE. ¼ of T. 11 N., R. 19 W. The maximum thickness measured is approximately 170 feet; however, the cover of windblown sands has made it impossible to find any break that might be considered the top of this almost solid sandstone member.

COLORS

In 1896 Cragin[21] made a division between the Wellington and Harper formations in Kansas which was based on change from non-

[21] F. W. Cragin, "The Permian System in Kansas," *Colorado College Studies*, Vol. 6 (1896).

red to red color. Since that time many attempts have been made to delimit formations by color, all of which have resulted in confusion. In the area here under consideration more than 75 per cent of the outcrops are red. The lines of color change are obviously transgressional across stratigraphic lines; consequently, the term "Red-beds" has been carefully avoided.

In several places color changes have been found to be closely related to the structure of an area. In general it may be stated that in the Upper Pennsylvanian gradations the red color is more pronounced where the percentage of sandstone is greatest. This is not applicable to the outcrops of Permian age.

DISCUSSION

MAXIM K. ELIAS, Lawrence, Kansas: In an attempt to recognize in this country the base of the Permian, which in Russia starts with the Artinskian conglomerate, the following kinds of fossils, which are known in the typical Permian beds of Russia, should be given greatest consideration: ammonoids, vertebrates, and plants. The recently introduced genus *Artinskia*, which is more primitive than *Medlicottia*, is known in the uppermost Uralian limestones in Russia, but extends also in the Artinskian, where it is found together with *Medlicottia*. The same stratigraphic relation of these two genera is observed in northern Texas, where *Artinskia* appears in the Wichita and true *Medlicottia* in the Clear Fork (the Wichita and the Clear Fork are understood here in the original sense as introduced by Cummins). Recently Romer concluded that a great change in vertebrate faunas, indicative of the beginning of the Permian age, occurs at the same horizon, at the top of the Wichita. Romer claims that there is a distinct unconformity at this horizon in northern Texas. Through correlation of Texas and Kansas sections, based on the study of the ammonoids and other invertebrates, this horizon in Kansas is somewhere within the Wellington shale. The evidence of the flora known from the Wellington in Kansas bears the conclusion as to the beginning of the Artinskian somewhere in the lower Wellington. It seems that the beginning of deposition of the Wellington or Geuda salt in Kansas may be taken as the beginning of the Permian time in the Mid-Continent.

JOHN G. BARTRAM, Casper, Wyoming: It has been suggested that some of the "red-bed" material in central Oklahoma came from the west or from the Rocky Mountain area. That appears improbable to me since the far western Rocky Mountain area was a sea and the only mountains were the continuation of the Wichita Mountains in Colorado and while they locally supplied Permian sediments, they were not large and could not have supplied much material as far east as Oklahoma. It appears more reasonable to assume that the "red-beds" were derived from a closer source. In the Triassic the Colorado highlands were almost completely buried and the Lower Triassic sediments could not have come from them and evidently came into the Rocky Mountain area from the south and southeast.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 20, NO. 11 (NOVEMBER, 1936), PP. 1476-1493

POSSIBILITY OF OIL AND GAS PRODUCTION FROM PALEOZOIC FORMATIONS IN EUROPE[1]

W. A. J. M. VAN WATERSCHOOT VAN DER GRACHT[2]
Heerlen, Holland

ABSTRACT

A large part of the oil and gas produced in North America is obtained from Paleozoic rocks. All the geological conditions required for accumulation and production are present in the Paleozoic fields of the Mid-Continent and Appalachian provinces. In Europe, practically no Paleozoic oil is known, though the geologic sequence and history are so similar in the two continents that geologists commonly point out the comparability. The only real difference is a matter of overburden, or depth below the surface. In Europe, there is a very thick blanket of Mesozoic and Tertiary formations overlain by heavy glacial drift. Admitting the many problems of folding and unknown complications with depth, the writer believes that Paleozoic accumulations of petroleum may be expected in Europe.

Reviewing the oil fields of the world, one is immediately impressed with the fact that a very considerable part of the production of the North American Continent is obtained from Paleozoic rocks. Truly, Mesozoic and Tertiary oil fields of spectacular importance are found in California, along the Gulf Coast and the Gulf Embayment of Texas and Louisiana, in Mexico, and along the foothills and in intermontane basins of the Rocky Mountains. In the entire Mid-Continent, however, from Texas to Canada, and in the eastern states along the Appalachian front, petroleum is exclusively produced from well consolidated sandstones, and in many places also from limestones of Paleozoic age, ranging from the Permian down even into the Upper Cambrian.

Cambrian gas occurs in New York state. Ordovician petroleum is produced in Ohio and eastern Indiana (Trenton dolomite), in Illinois (Middle Champlainian), in Kentucky and Tennessee, in Michigan (Devonian and Ordovician), in Kansas, Oklahoma, and central Texas (Ordovician "Wilcox" sands, and Cambro-Ordovician Arbuckle limestone). Ordovician now constitutes the major prolific horizon of high-grade petroleum in the states of Oklahoma and Kansas.

Lower Silurian oil is found in the Medina and Guelph formations of Ontario.

[1] Read before the Congrès International des Mines, de la Métallurgie et de la Géologie appliquée, VII Session, Paris, October 20–26, 1935, and printed by the Congress under the title, "Pouvons-nous espérer découvrir du pétrole et des sources de gaz naturel exploitables dans les formations paléozöiques en Europe?" English translation received from the author, September 24, 1936.

[2] Director, Netherlands Bureau of Mines.

Upper and Middle Devonian and Lower Carboniferous petroleum is produced from sandstones and some limestones in several oil fields along the western foothills and on the foreland of the Appalachian Mountains, the most of it from the Lower Mississippian and Upper Devonian, at or near the unconformable contact of these formations, in New York, Pennsylvania, West Virginia, Ohio, Kentucky, and Tennessee; also from limestones in the Rocky Mountain region in Alberta, Montana, Wyoming (Lower Mississippian Madison limestone); and in Michigan petroleum is produced from Mississippian and Devonian rocks (Berea).

Upper Carboniferous to Lower Permian petroleum is produced from the upper horizons of the Appalachian oil fields, but notably throughout the Mid-Continent, in Illinois, Missouri, Kansas, Oklahoma, north-central Texas; and in the Rocky Mountain region, in Utah, Colorado, and Wyoming (Tensleep formation).

Upper Permian petroleum is produced abundantly from dolomites and limestones in the Great Salt basin of West Texas and eastern New Mexico.

Why is it then that in Europe Paleozoic oil fields are practically unknown?

So far there is a little, rather disappointing production from saline Permian dolomites in Germany, notably in Thuringia (Volkeroda); a very little Upper Carboniferous oil, so far without practical importance, in the English Midlands (Hardstoft), and rather widespread promising occurrences on the western flank and the foreland of the Ural Mountains (Tschussovaija, *et cetera;* and some Upper Devonian oil in the Timan Range (Uktha).

This differs very greatly from what is found in North America!

There is no geological reason or explanation for this striking incongruity Oil fields are dependent on two major requirements: first, the presence of suitable source rocks, where primary bitumens have been deposited and preserved, and, in the course of geologic time, have been changed into free liquid and gaseous hydrocarbons; second, the presence of reservoir beds on suitable structure, into which oil or gas could migrate and segregate from the salt water, which is connate, not with the sediment, but with the hydrocarbons. It seems very probable that the highly saline water, with excess of calcium, iodine, and bromine, in some places also potassium, which is regularly found associated with oil pools, is no fossil sea water, but a segregation product of the original organic material: organisms which have concentrated these rare constituents of sea water in their tissues.

These conditions are not restricted to any particular geologic

formation or period; they occur in sediments of all ages, even to present time. Even the oldest sedimentary rocks of Algonkian, pre-Cambrian, time contain ample evidence that source rocks and reservoirs of petroleum have been far from rare. These deposits have been changed by metamorphism into graphitic shales, quartzites, and schists, even gneisses, and oil-filled fissures have been turned into graphite veins, which originally certainly must have been veins of asphalt (Ceylon).

The Paleozoic oil province of North America is particularly developed on a plateau, which extends southward from the Archean Canadian shield, and constitutes the foreland of Paleozoic, mainly Permo-Carboniferous, mountain systems which frame it on the east and the south. Similar chains probably existed at one time in the west, in a region now entirely remodelled by the Mesozoic and Tertiary Cordilleran orogeny, and possibly out on the shelf, off the present Pacific coast. This Mid-Continent plateau was the only slightly warped, thoroughly solidified foreland of the Appalachian and Ouachita mountain belt, which was pressed against it at the end of the Paleozoic era. This plateau was part of the continental mass, but during all Paleozoic time it was repeatedly submerged and covered by shallow epi-continental seas, which in certain belts of geosynclinal subsidence may locally have been deeper, while several older nuclei tended to persist as emerged islands. Not uncommonly certain areas of regressing sea water contain concentration deposits, in many places actual salt, in various stratigraphic horizons, notably in the Silurian and in the Permian. This epi-continental and particularly also the saline, at least concentration, facies, is commonly accompanied by the deposition of source rocks of petroleum.

WHAT IS A SOURCE ROCK AND WHAT IS A RESERVOIR?

1. Some have thought that there exists a relationship between petroleum and coal. These substances have been, in fact, deposited under conditions which were in a certain way related, either in place or in time. However it is now practically generally admitted by geologists, that the source environment of petroleum is quite distinct from that of coal; the coal-measure facies is adverse to the formation of free liquid bitumens.

David White[3] recently expressed this in a posthumous paper as follows.

The mother substances from which, chiefly, oils are derived, consist pre-

[3] David White, "Metamorphism of Organic Sediments and Derived Oils," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 5 (May, 1935), p. 590.

dominantly of the remains of aquatic life, plant and animal, of low forms composing typically a sapropelic plankton or colloidal saprocol mixture, relatively fatty or rich in hydrogenous high-volatile substances and low in oxygen. The organic matter of coal, on the other hand, is overwhelmingly composed of vascular, terrestrial plant débris . . . , in general characterized by high-oxygen carbohydrates, the deposits being rich in humic products and relatively low in volatile matter.

Naturally both groups may intergrade laterally, that is in place, in coastal zones, or vertically, that is in time, as the swampy coastal flats of the coal measures succeeded a deeper-water marine condition, or *vice versa*.

In the writer's opinion, the source rocks of true free petroleum and real oil gases are exclusively of marine, at least salt-water, origin. His views have been reached after consideration of world-wide research work on modern marine sediments, executed in part under his guidance by P. D. Trask, and the recent independent work of K. Krejci-Graf, F. E. Hecht, R. Potonié, and many others. He has come to the conclusion that source rocks of commercially important accumulations of petroleum belong exclusively to two somewhat related classes of sediments: (1) those of the "euxinic facies," typically present to-day in the Black Sea (Pontus Euxinus) and which, clearly, have been occurring locally through all geologic time, and (2) sediments of a moderately "saline facies," where the sea-bottom is covered by water of strong saline concentration. Both environments have this in common, that organisms, which may be exceptionally prolific under these circumstances, are confined to the upper horizons of more or less normal water, while the deeper and notably the bottom layers of the water are devoid of oxygen, and contain poisonous admixtures, principally hydrogen sulphide, which exclude life on the bottom ("benthos"). In consequence, all organic sediments, sinking from above, chiefly plankton, are preserved from attacks by the numerous scavengers which abound on all normal sea-bottoms, and become fossilized. In the present Black Sea, with a depth exceeding 2,000 meters in places, only the upper 100–200 meters of water contain sufficient oxygen to support life; all the deeper water is poisoned by hydrogen sulphide, liberated by sulphur bacteria. The black sediment contains 23–35 per cent of organic matter, and is devoid of any living thing, except anaërobic bacteria and ciliates. It is the exceptional, relatively rare circumstances that bottom life is excluded, which permits the formation of rocks sufficiently rich in preserved organic material to be considered as source rocks of petroleum.

We find undeniable evidence of a euxinic facies in all geologic formations. These rocks are black, sulphurous, pyrites-containing muds;

fossils are rare, and confined exclusively to siliceous or chitinous remains of floating organisms, mostly small plankton forms which are largely devoid of any shell or skeleton, fish scales, brachiopods which float attached to seaweed (*Lingula, et cetera*), or buoyant shells of cephalopods. In the old Paleozoic rocks, graptolites, also planktonic organisms, are conspicuous. Paleozoic crinoids may also have floated attached to weeds, *et cetera*. Source rocks of the saline class are found in deposits of concentration basins, before or after deposition of actual rock salt, at a time when strong salt solutions prevailed at the bottom, but the less salty upper layers of the water supported life. It is not necessary that the stage of precipitation of actual salt was ever reached; the cycle may have been interrupted. Concentrated brines are not only adverse to life; but they also prevent convection currents and access of oxygen to the deeper layers of the water. These saline rocks are generally dark, sulphurous, and bituminous dolomites and gypsiferous shales (Stinksteine).

2. In these source rocks the bitumens originated. In nearly all commercial oil fields, however, production is not obtained from the primary source beds, but from secondary (allotigenous) reservoir rocks into which liquid and gaseous hydrocarbons have accumulated, after various still rather obscure processes have set them free, and after they migrated along the gradient of decreasing pressure in the sedimentary sequence (this means preferably upward). Diagenetic processes are the first requirement for conversion of the primary bitumen into free oils and gases. Moderately elevated temperature, very high pressure, and the length of geologic time play the dominant parts, but other factors as radioactivity and catalytic contacts very probably contribute, causing polymerization of unsaturated hydrocarbons.

Reservoir beds, containing commercial oil or gas can be of every petrographic description or geologic age, provided they possess adequate porosity. They may be marine or continental sediments, sands or sandstones, gravels or conglomerates, oölitic or otherwise pervious beds, even porous igneous rocks or their derivatives (Texas). Source rocks, however, must be in the vicinity. In very many places typical source rocks are now known to underlie oil pools at greater or lesser depth; in practically all other places there is reason to assume their presence, while reservoir beds are mostly of a nature which excludes primary (autigenous) petroleum.

Where a stratigraphical sequence contains numerous porous strata, a structural oil field generally contains several superimposed producing horizons—"oil sands." The general section of the pool presents a more or less conical "stockwerk" of petroliferous horizons, nar-

rower toward the top and laterally wider toward the base. The productivity in each individual "sand" is dependent on its petrographic aptitude as a reservoir, but in general—provided porosity is adequate—these nearer to the autigenous source beds are richer. The oils differ vertically, in a manner that can be explained either as a consequence of filtration, admixture with other oils or vapors, or through oxidation in contact with surface waters, or otherwise. Gas not associated with, or dissolved in, oil is mostly characteristic for the uppermost sands.

In the writer's opinion, migration must be assumed to occur chiefly in a vertical direction, toward the surface, in accordance with density and the gradient of pressure. Lateral migration, especially in widespread, continuous blanket sands of high porosity, like the "Wilcox sand" at Oklahoma City, and the Woodbine sand in East Texas, must be admitted.[4] The successive oil sands of a petroleum stockwerk may be separated by major unconformities and stratigraphical hiatus (Oklahoma City, *et cetera*), or even by great overthrust faults (Borislaw), in consequence of which petroleum impregnation affects beds, which originally have been deposited miles apart. Migration may vertically traverse two or more overthrust slices. In some places the supply of oil seems to have stopped at an unconformity and not to extend to younger beds; in other places the infiltration takes place without obstruction. This suggests that conversion and migration may start at some time considerably later than the deposition of the source sediments, and may, or may not, be renewed and may occur in different successive crops, probably induced by diastrophism.

Upward migration must not be thought as being prevented, though it is relatively impaired, by supposedly impervious strata, like dense clays, *et cetera*. That volatile hydrocarbons actually did pass such layers is obvious. The earth's crust is perpetually, though variably in motion, by micro- as well as macro-seismism. Imperviousness and rigidity are only relative terms. Finest cleavage and partings in rocks probably play a far more considerable part than fissures in opening a way for migration.

In accordance with the upward direction of migration, we find that, in general, asphaltic (oxidized) oils decrease in density with depth; paraffine oils, however, increase in density with depth. Commonly the asphaltic oxybitumens overlie deeper paraffine oils, although there are exceptions. Asphaltic deposits and inspissated oil

[4] R. W. Brauchli, "Migration of Oil in Oklahoma City Field," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 5 (May, 1935), pp. 699–701.

of a previous cycle of migration may occur at or near old buried land surfaces along unconformities, and be overlain by paraffine oils in younger strata, filled by a later cycle of migration. Only access of oxygen, at whatever period, seems to count, but there is some indication of the influence of calcium salt on the formation of asphaltic products low in oxygen.[5]

All the requirements, reviewed in the preceding paragraphs, for the occurrence of commercial petroleum are conspicuously present in the Paleozoic oil and gas fields of the North American Mid-Continent, the Appalachian province, as well as the Mesozoic and Tertiary oil province of other North American and European regions, or elsewhere. Do the Paleozoic formations of Europe meet these requirements?

In Europe, as already stated practically no Paleozoic oil deposits have so far become known. Is the geologic sequence or history of the Paleozoic sufficiently different to explain this discrepancy? It is not. In fact they are so similar that several geologists use this comparability as an argument for continental drift and an original continuity of the Eurasian and North American continents. This similarity applies in part to the older Paleozoic rocks; in the Silurian a euxinic graptolite environment was probably much more widely spread over western and southeastern Europe than on the North American continent. The sediments of the Upper Devonian and Carboniferous eras were almost identical on both continents for the areas on the immediate foreland in front of the Permo-Carboniferous mountain systems, so much so that their original continuity is considered almost a necessity. All along the Variscan front of the late Paleozoic mountains of western Europe, the identical development exists in the foredeep deposits of the Upper Devonian and the Lower Carboniferous, again with prevalence of a conspicuously euxinic facies, notably in the Culm of Europe; the environment was obviously the same as in front of the Appalachian and Ouachita mountains of North America. On both continents these older marine formations were succeeded by a "Subvariscan" (Stille) development of very thick coal-bearing Upper Carboniferous coal measures (Pennsylvanian), grading upward into Lower Permian.

The only real difference is a matter of overburden. On much of the North American continent Paleozoic rocks practically form the surface (under a variable, not excessive cover of glacial Pleistocene in the north). This holds especially true for the foreland of the Appa-

[5] Karl Krejci-Graf, "Fortschritte der Oelgeologie," *Geol. Rundschau*, Vol. 26 (1935), with an extensive bibliography.

lachian Mountains, so well known for its oil fields. In northern Europe, however, this foreland is buried under an extremely thick blanket of Mesozoic and Tertiary formations, and these in turn under a heavy layer of glacial drift. This is particularly true for the North German and Dutch plains, and the region now accidentally submerged under the North Sea.

Consequently, the conditions on the foreland are heavily obscured in Europe, though in North America they are beautifully exposed and were easily ascertained. Coal mining has not proceeded far north from the outcropping coal measures in the foothills of the Variscan Mountains of Europe. It stopped where the overburden had increased to 500–600 meters. Drilling has explored the Carboniferous subsurface considerably farther, under a covering as thick as 1,400 meters. This northern limit of actual information extends approximately from Detmold and Münster in Westfalia, over Winterswijk-Helmond-Bergen op Zoom in Holland. Over most of the region farther north the Paleozoic basement is not only unknown, but entirely inaccessible; in most of North Germany and the Netherlands the depth probably exceeds 6,000 meters. Only around Osnabrück the later uplift of the Teutoburgerwald has lifted a block of uppermost Upper Carboniferous, still in coal-measure facies, to, or very near, the surface. In consequence, one can only speculate as to the structure and the probable nature of the rocks in the Paleozoic sequence under most of the vast Plains basin of northwestern Europe. The writer has always been fascinated by this problem.

The regional structure of the area must be fundamentally similar to that of the much better exposed Mid-Continent of North America, which is a plateau-like extension of the Archean Canadian shield. Something of the same nature may be expected for the Paleozoic foreland of the Variscan Mountains of Europe. Here the foreland, not unlike the much better exposed Russian tableland, should be a downwarped extension of the Fennoscandian shield, under a cover of generally only gently warped, but much more heavily faulted, Paleozoic strata. The Variscan folding gradually dies out toward the north, and has practically disappeared at Osnabrück, Winterswijk, and in the Belgian Campine, north of the Brabant massif. It is still fairly in evidence at Münster in Westfalia. The Paleozoic rocks should comprise a more or less complete sequence from Upper Cambrian to Upper Permian inclusive, with a considerable gap in the Lower and Middle Devonian (as in America) and—probably— a further gap at the top of the coal measures under the Upper Permian.

In this part of Europe, though, the structure is complicated by a

Mesozoic-Tertiary refolding of this deeply buried basin and its thick series of younger sediments: the Saxonian orogeny, the folds of which strike west-northwest, obliquely across the east to east-northeast Paleozoic trend. These Saxonian folds can be traced from Poland east of the Pennine axis of England. This complication, which is probably a consequence of the enormous subsidence, is absent in the Paleozoic areas in North America, except in the Gulf Coast basin. Moreover, the Permian sediments are largely in a saline facies and contain great deposits of rock salt, buried at great depth. In consequence, typical salt tectonics complicate the structure; in addition, in the deeper parts of the basin, evidence of upthrust of innumerable salt domes is encountered.

Another problem, this one concerning the deeper basement, is caused by incertitude about the influence of an older Paleozoic orogenic cycle, which caused the Caledonian folds and thrusts of the British Islands and Scandinavia. Stille and others believe this older folding to extend into the sub-basement of the plains. The writer, however, believes that notable folding dies out not far east of the Pennine axis of England, and that the present continental region remained practically unaffected. It has been stated that the very steeply inclined old rocks on the Brabant massif, as viewed in outcrops and encountered in wells, give evidence of considerable Caledonian folding in this region. The writer, however, is inclined to doubt whether the very steeply dipping, north-striking, metamorphic, greenish schists and quartzites on the massif, in the valleys of the Dyle, south of Wavre, and of the Jette, around Jodoigne, named the Devillien formation by the Belgian Geological Survey, are of Cambrian age. These rocks differ greatly from the normally east-striking graphitic slates of the Revinien, which is probably correctly considered as Cambrian, since they underlie fossiliferous Ordovician. This Devillien might be much older Algonkian. Traces of fossil algae are very inconclusive.[6]

It is possible, therefore, that these highly folded rocks in central Belgium belong to an earlier pre-Cambrian orogenic cycle, and have no connection whatever with the late Silurian Caledonian revolution. A little farther south, in the Ardennes, there is no evidence of strong Caledonian folding, and in the Harz Mountains and in Thuringia it is confined to slight unconformities, such as those which are common on the American Plateau.

It seems therefore, that facies and structure being so similar to

[6] J. de la Vallée-Poussin, *Mem. Inst. Geol. Univ. de Louvain*, Vol. 6 (1930), pp. 319–53.

those on the Appalachian foreland and the Mid-Continent of America, Paleozoic accumulations of petroleum could also be expected in Europe. If temperature and compression are major factors inducing conversion of bitumens in the source rocks and their migration upward, the very great depth of burial of the probable source-bed horizons in the northwestern European basin should be favorable, provided there exist suitable reservoir beds at a workable depth, where uprising oils and gases could accumulate. There is no certainty, however, how far the favorable euxinic facies of the Lower Carboniferous Culm may extend north, but it is very probable that it persists in those regions where the Paleozoic floor remains within workable depth.

Frequently the objection is heard that the vast regions in Central Europe, where the Paleozoic formations crop out, or in the adjoining belt where they are worked in the Westfalian, Dutch, and Belgian coal mines under a moderate overburden, are conspicuously devoid of petroleum, although a few scattered small showings must be noted. This, in fact, may be the main reason why so far European petroleum geologists have not considered the possibility for Paleozoic oil farther afield.

In the North American oil provinces, however, exactly the same phenomena exist. Neither within the Appalachian Mountains of the east, nor in the Ouachita and Wichita mountains of the middle-west and the southwest, are there any oil fields. These occur only at a certain distance out from the mountain front. First gas fields appear, with a few isolated pockets of very light-gravity petroleum, practically gasoline; it is only still farther out that the real oil fields are found, in a belt parallel with the mountains. In the Appalachian fields the first gas fields appear approximately 50 kilometers from the sharply defined mountain front; the belt of oil fields lies 90–150 kilometers out.

The reason is well known: it is regional metamorphism in connection with the mountain-making forces.

To a large extent and with comparatively few exceptions oil fields occur on gentle structures, in areas of comparatively little folding. Plateau regions are specially preferred, chiefly the forelands of relatively more recent orogenic zones. They formed the framework against which the later folds were directed, and in the depressed belt, the foredeep, which generally fringes the mountain front, accumulated great quantities of outwash sediments from the highlands, in a commonly favorable environment for the formation of source beds of petroleum. The mountain chains are characterized by intense folding

and overthrust structure, but the formations have a tabular distribution over the peneplaned older surface of the foreland, and have only been gently warped, or dislocated by faults.

Accumulations of petroleum are not only formed, but they are also commonly destroyed by subsequent geological events. Within strongly folded mountain belts, the chances against conservation of oil deposits are very much greater than in relatively more quiet regions. This is the reason for the relative scarcity of oil fields in strongly folded rocks. They are much more numerous in the foothills of the outer zone of the chains, where folding is much reduced, or on the only gently warped tabular foreland. Other gentle structures occur in depressions in the interior of mountain systems, which are filled by less disturbed later sediments.

The reasons for the destruction of many oil deposits in strongly folded mountains are erosion and dispersion.

The effect of erosion is simple and needs no further discussion.

The violent dynamic thrust within the orogenic zones, ordinarily accompanied by a downward buckling of the crust into considerable depths, and resultant injection of igneous rocks or mineralized solutions and vapors, cause chemical changes in the strata, which are called regional metamorphism. This may occur to a very variable degree. It may be so intense that the entire mineralogical aspect of the strata is profoundly changed. Even comparatively recent sediments can thus be transformed into crystalline rocks—schists, marbles, and quartzites—which can not be distinguished petrographically from pre-Cambrian formations. In other places metamorphism is so slight that silicates and other rock-building minerals are not visibly affected, but some incipient cleavage generally proves the stress. It is now known, however, that bitumens and coals are much more sensitive to chemical influences of this nature. All the known oil fields of the world occur in unmetamorphosed or only very slightly altered sedimentary rocks, but natural gas is found able to survive a somewhat greater alteration. Strongly metamorphosed rocks are barren of oil deposits, unless the oil entered by subsequent infiltration.

Where the strata affected contain coal seams, these can effectively be used to indicate the amount of the very moderate metamorphism, which is not strong enough visibly to affect inorganic minerals. Slight metamorphism turns bituminous coals into harder varieties with less volatile constituents, and finally into anthracite. This was demonstrated with special clearness in the Appalachian coal fields of the eastern states of North America, where both oils and coals occur, and the gradual changes in the same seams of coal can be traced from

the undisturbed foreland to within the center of the mountains. The same process is more or less clear in evidence throughout the world. A map showing the regional carbon-ratio variations in Pennsylvania, Maryland, Virginia, West Virginia, eastern Ohio, eastern Kentucky, and adjacent regions, was published by Eby[7] in 1923 and by White[8] in 1925. White[9] elaborated this considerably in the previously cited posthumous paper.

Many now believe that petroleum is affected in a very similar manner. The process must be very much related to the cracking processes used in petroleum refineries for the conversion of heavy oils into lighter varieties, chiefly gasoline, where the surplus carbon is left in the form of petroleum coke. In nature the effect of progressive regional dynamic alteration is also marked by a concentration of hydrogen in the distillates and a concentration of carbon in the residual débris. Metamorphism, consequently, lowers the specific gravity of the oils, so much that in the more strongly affected zones only gas fields remain and, finally, where metamorphism becomes more intense, no trace of oil or even gas is left, although general conditions remain equally favorable for the presence of oil fields. All this takes place within zones, where there is not yet any visible change in the rock-building minerals of the sediments, except some moderate induration and incipient cleavage. Where coal is present in the oil-bearing section, as in the Appalachian oil fields, it can, therefore, in some place be used effectively as a natural recorder of the local intensity of metamorphic action to which the associated strata have been subjected, and the quality of coals can be used as an indicator for the position of the metamorphic extinction zone, or "deadline," limiting the occurrence of commercial oil pools. The contents of fixed carbon is used, as shown by proximate analyses of coals, calculated to the ash-, moisture-, and sulphur-free basis. The determination of fixed carbon by ordinary proximate analysis, as generally used in industry, is unreliable.

This so-called "carbon-ratio theory" is often used to estimate possible oil occurrence in unprospected territory, but it has to be applied with circumspection; it has by no means such validity that a certain carbon-ratio in some coal excludes all possibilities of finding commercial oil deposits in the vicinity. It is still less permissible to state

[7] J. B. Eby, *Virginia Geol. Survey Bull. 24* (1923), Pl. 37.

[8] David White, "Progressive Regional Carbonization of Coals," *Trans. Amer. Inst. Min. Met. Eng.*, Vol. 71 (1925), p. 267, Fig. 2.

[9] *Idem*, "Metamorphism of Organic Sediments and Derived Oils," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 5 (May, 1935), pp. 589–617.

that a certain degree of folding excludes the possibility for the conservation of oil deposits. Orogenic pressure may locally have been relieved by the yielding of the beds in folds or faults, especially in overthrust zones. Regional metamorphism is clearly influenced by competency of the strata. Where the rocks can yield by folding, and especially by overthrusting, stress is obviously relieved: coals are less carbonized, and oil may be found in a locality well behind the extinction zone. A notable example is the occurrence of oil in the Rose Hill tectonic "fenster" in southwestern Virginia; here the coals also show a notable drop in carbon ratio, evidently due to relief of metamorphosing stress through the overthrust.[10] Some oil seeps are also known well within the highly folded and thrust part of the European Variscan Mountains, both in Belgium and in Germany.

There also is a well known progressive carbonization of coals downward in the vertical section, the so-called "law of Hilt." This indicates that metamorphism increases with depth. It does not follow, though, that there is such a thing as a lower extinction zone, merely dependent on absolute depth. In other words, it can not be stated that below certain depths no oil could have been preserved. It seems apparent that the regional metamorphism, as expressed by carbonization of coals, is principally caused by orogenic stress and much less by the weight- and temperature-increases caused by overburden, not consequently by the absolute depth of burial. Once metamorphism is present, the depth below the surface may influence its degree, particularly the depth of burial at the time the metamorphosing stresses were active. Metamorphism occurred at times of increase of orogenic activity to a greater intensity than before. Competency again plays its part, as indicated by anomalies in the same vertical section, in some places reversals. These successive downward advances in carbonization from coal to coal may be due, in some measure, to the temperature increment, the effectiveness of which is given exponential value by geologic time. If all this is true of coals, it probably is true also of oils.[11]

The major factor, therefore is tectonic pressure, especially where the beds withstand it without, or before, considerable deformation.

The temperature to which source rocks, or accumulations of petroleum, were subjected in folded regions may not have been considerable. There are some indications of this in the records of very deep wells drilled in California. This is in a zone of great present orogenic activity. In the Belridge field a temperature of only 100°C.

[10] David White, *op. cit.*, p. 594.

[11] David White, *op. cit.*, p. 597.

existed at a depth of approximately 3,500 meters. Here the stress may be as active and the strata may be under as great pressure and as hot as they ever were.

Where no great orogenic pressure exists, the mere depth factor should not be very important.

Since workable deposits are always secondary reservoirs, probably the conditions in the source zone count most. Local variations due to competency and to yielding may exert a different influence at great depths. Evidently these factors must be expected to vary considerably from one region to another, and too rigid conclusions should not be drawn as to the degree of folding that is destructive for oils. Notable instances of prolific production in highly folded rocks are the Turner Valley field in Alberta and the oil pools around Borislaw in the Polish Carpathians.

All this explains the natural absence of oil fields in the strongly compressed exposed part of the Variscan chains of Europe, and also within the immediate forezone, now worked by coal mines. It also explains the possibility of fields at variable distances away from the mountain front. It has been discussed in preceding paragraphs how this is very clearly demonstrated in the Appalachian oil province of North America.

WHERE IN EUROPE SHOULD PALEOZOIC OIL BE SOUGHT?

A search for Paleozoic oil in Europe should leave the outcrops in Central Europe and move out on the foreland. If it is desired to test the Paleozoic formations themselves, not too far above their possible source zones, the territory is very limited relative to the great extent of the buried foreland plateau. Far out in the northwestern Plains basin of Europe the depth of the Lower Carboniferous, or possibly even older (Silurian ?) source zones, provided they are present in suitable facies, must be very excessive, possibly 10,000 meters or more. What may have happened to bitumens under those conditions no one can say, except that the products of any alteration must have gone somewhere in their long way to the surface, and may have been reformed and accumulated in other horizons. Doubt has often been expressed whether all or most of the oil encountered alongside of some of the North German salt plugs had anything to do with the formations in which it is now found. It has even been doubted whether the Permian saline dolomites should be considered a sufficient and plausible source. It is not impossible that still deeper sources may have been an original factor.

The writer has had the good fortune to become acquainted with

persons with sufficient means, vision, and enthusiasm, to make them willing actually to test the possibility of Paleozoic oil fields in western Europe, provided some sufficiently promising locations could be made.

It follows from the foregoing discussion, that it was first of all required to outline a suitable region, at sufficient distance from the Variscan mountain front, outside the belt where coal mining had already demonstrated that porous sandstones in the coal measures were barren of oil or any distinct petroleum gases. It had also to be borne in mind that it is out of the question to expect autigenous source beds in the coal measures, but that coal-measure sandstones can very well contain, as they do in America, important secondary accumulations. In the Appalachian oil fields these are richest in the vicinity of the Lower Carboniferous source beds; hence, it would be advisable to look for a location, where the source horizons would not lie at too excessive depths; if not all formations could be reached, modern deep drilling should be able at least to approach the nearer formations in the section.

One of the few areas, a considerable distance north of the strongly folded areas, where the Paleozoic rocks can be reached at reasonable depth, is the "Rheinische Masse" in Westfalia, south of the Teutoburgerwald. There is the additional advantage that the subsurface and the depth to the Upper Carboniferous below the thick cover of Upper Cretaceous, have already been proved by drilling for coal, as far north as the city of Münster, where the depth does not exceed 1,400 meters. Here east-northeast Variscan folding still exists; there are also indications of the first undulations of the west-northwest striking Saxonian folds, which gain very considerable importance in the hills of the Teutoburgerwald, only approximately 50 kilometers north. Here they are still unimportant and will not complicate the problem. The "Rheinische Masse" is a relatively highly elevated Paleozoic massif, buried beneath the Upper Cretaceous of the basin of Münster, and bordered on the north and the east by great downthrown faults, which in a series of steps, from the "Westfälische Hauptabbruch," more or less parallel the inner border of the Egge-Osning arc of the Teutoburgerwald. Beyond these faults a great thickness of Jurassic, Triassic, and Upper Permian becomes intercalated between the Cretaceous and the coal measures; in a short distance farther north also considerable Tertiary is added on top of the Cretaceous, and the Paleozoic is too deep for practical consideration, except on a few specially elevated blocks on the axes of the Teutoburgerwald, notably around Osnabrück.

The relatively regular Variscan folding permits the tracing of the

general trend of the major anticlines under the Cretaceous covering, and remains sufficiently pronounced to create a rather regular pattern and not the extremely confused structural picture of such very gently undulated areas as exist in the American Mid-Continent.

The bordering faults sweep sharply toward the south, east of Lippspringe and Paderborn (as indicated by borings described especially by H. Stille); they cut off the Paleozoic mass from the depression of Hessen on the east.

This typical, regional "high," therefore, must be considered as particularly favorable for possible local accumulations of oil and gas at reasonable depths, provided such hydrocarbons are present.

Another, theoretically not unpromising, region is the northern part of the Belgian Campine, where the coal measures are found again north of the Brabant massif, and where there is evidence that the Variscan folding ends within a short distance. Here also it would be necessary to go north of the zone where present coal mining is active in Holland and the Belgian area around Genck, Asch, and Helchteren, without being troubled by any indications of petroleum.

In both regions, in Germany and in Belgium, there are indications of petroleum gases, north of the mining districts.

In the first-mentioned region, south of Münster, an active drilling campaign for coal was conducted in the years between 1902 and 1907. Many of these borings developed considerable trouble with inflammable gases, which repeatedly caused disastrous blow-outs and even fires, because of great pressure. In addition there were some showings of asphalt, liquid tar, and even oil in some wells and in excavations.

These indications were particularly numerous in an east-northeast trending zone between the towns of Lüdinghausen and Sendenhorst, and notably between Ascheberg and Drensteinfurt. Further geologic work indicated that these important gas wells appeared to be located on a considerable, normally trending anticline in the basement, obliquely crossed by a northwest-striking elevated complex fault-block.

These gas wells have been described by Müller,[12] Wegner,[13] and Grotensohn.[14] Particularly 14 of these wells are interesting for this particular structure; one of them, east of Ascheberg, was completed as a gas well, and now, after 30 years of its existence, still shows a closed-in pressure of about 30 atmospheres (approximately 400 pounds), and wet gas, not only strongly smelling of petroleum, but actually yielding considerable gasoline on absorption tests. These

[12] G. Müller, *Ztschr. f. prakt. Geologie* (1904), pp. 9–10.

[13] Th. Wegner, *Glückauf* (1924), Nrs. 30–31.

[14] A. Grotensohn, *Petroleum* (1934), Nr. 5.

gases generally began to show in the fissured limestones of Turonian (Plänerkalk), and especially in sandstones in the top of the coal measures. Unfortunately none of these wells was drilled in for any considerable depth, their sole object having been to prove the presence of a coal seam in order to obtain mining rights under the German law. The gases were originally explained as coal gas, given off by coal seams, and they received no practical attention, except as a rather unfavorable indication of trouble to be expected in eventual coal mining. Though some of the very few gas analyses made, notably at Ascheberg, showed 2.2–3.6 per cent ethane, and even some heavier fractions, mixed with 92–97 per cent methane, nobody of the mining fraternity seemed seriously to consider the possibilities for petroleum. Drippings of volatile oil at that time were noticed and collected, and were finally placed in the town museum at Münster. The natural gasoline condensate, recently obtained in considerable quantity by Schenck, proved beyond any doubt that these gases are real petroleum gases.

In a few other scattered localities in Westfalia, fewer wells obtained similar showings. Investigation showed that some of these were also connected with favorable structure.

That these gases were oil gases had already been recognized in 1924 by Wegner.[15] In the same year, K. Hummel[16] even pointed to certain similarities with the Appalachian oil belt. Generally, however the opinion prevailed that these gases had their origin in the coal measures, or that very deeply buried coals could be a source of petroleum. That this is not the case has already been discussed in this article. No practical conclusions were drawn as to the possible economic significance of these gases, except by the geologists already mentioned.

The gas wells near Ascheberg are located 12 kilometers north of the trend of the northernmost coal mines near Werne, Hamm, and Ahlen. It is noteworthy that most of these mines are more or less troubled by rather excessive quantities of inflammable gas, which sometimes smells of petroleum. An analysis of mine-gas near Ahlen actually showed ethane.

The complete section of the Upper Carboniferous coal measures of Westfalia attains a thickness of possibly 4,000 meters, from the marine horizon above the Aegir coal down to the Lower Carboniferous Culm. At Ascheberg evidence is lacking about the horizon that may underlie the Cretaceous on the crest of the structure. Possibly the Culm may

[15] Th. Wegner, *op. cit.*

[16] K. Hummel, *Petroleum* (1924), p. 115.

be 2,500 meters below the top of the Paleozoic section, as represented in this locality, meaning that the actual source horizons in the Culm would be 4,000 meters, or even more, below the surface. Sandstones, perfectly suited as reservoirs, however, are common through the entire section of the coal measures, and become notably abundant and coarse in zones which might be reached at a depth of 2,500 meters below the surface. The same applies to Belgium, but here the thickness of the coal measures is reduced.

Although the quality of the gases already indicates conditions beyond a possible metamorphic extinction zone, this is further proved by the absence of notable carbonization of the coals, which in fact, in Westfalia tend to increase in volatile constituents toward the east rather than to decrease. In the Campine the same condition exists but in the westerly direction.

In consequence of the foregoing considerations a location was made for a deep test just east of Ascheberg, on the main road from Münster south toward Herbern. Machinery of the heaviest and most modern type has been provided, operated by an experienced crew, thus making it possible, if necessary, to go down to the greatest depths modern technique will permit.

After geophysical investigation, another test was located in the Belgian Campine, near the town of Moll, 23 kilometers almost due north of Dienst. This test is provided with the same type of machinery as the well at Ascheberg, and at the time of writing has reached a depth of 650 meters. The Paleozoic may be expected at approximately 1,000 meters. This well has also already confirmed the expectation of gas in the younger formations and reached the coal measures at 893 meters. This well is 15 kilometers north of the northernmost coal mines of the Campine (Beeringen). The section above the Paleozoic consists of Oligocene, Eocene, Paleocene, and Upper Cretaceous.

At the present moment (September 1, 1936), both wells have reached a depth of about 1,500 meters and continue to show gas. Three additional wells were started in Westfalia: another some distance west of the same Ascheberg structure, one near Kiltrup, and one at Oelde.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 20, NO. 11 (NOVEMBER, 1936), PP. 1494-1496

DISCUSSION

GEOLOGY OF THE TAMPICO REGION, MEXICO

John M. Muir's *Geology of the Tampico Region, Mexico* is a much appreciated contribution to the knowledge of the area.

It is quite natural that a work of its scope should involve some controversial points, on one of which I comment because it refers to part of a statement of mine published in 1928.

On page 47 of Muir's work is the following.

> White (195, p. 178) shows a hiatus between the Tamaulipas limestone and the Agua Nueva (referred to as "San Felipe"). There does not seem any good ground for this view. No palaeontological evidence is available to show that the Upper Cenomanian is missing.

This is in reference to my statement in the *Journal of Paleontology*, Vol. 2, No. 3 (September, 1928), page 179,

> On the high structures of the producing areas, there is an abrupt change in both lithology and character of the microfauna between the San Felipe and Tamaulipas, due to a hiatus. In the synclinal areas of greater deposition, the hiatus between the San Felipe and Tamaulipas becomes less pronounced and in some places the relation is conformable.

The range charts accompanying my paper here cited ("Some Index Foraminifera of the Tampico Embayment Area of Mexico") emphasize the hiatus and do not show the cases of transition or conformable relationship.

On the other hand, in the drilling of its Naranjo tests, referred to by Muir, some distance from the Panuco area, the International Petroleum Company found a transition from what was then called San Felipe to Tamaulipas. The gradation here is very pronounced both in lithologic and in paleontologic character. It caused considerable confusion in locating the top of the Tamaulipas, particularly for those not using paleontologic evidence.

What had been an abrupt break from gray San Felipe shales to white Tamaulipas limestone on the producing "highs," became an alternating series of the two, for some distance, containing a combined fauna, which was missing over the Panuco producing area. Of the 19 index forms found in well cuttings and listed for the San Felipe, 17 range up into the formation above but only 2 range down into the Tamaulipas and those 2 are included among the forms ranging above the San Felipe. This indicates an abrupt change between the beds separated by the hiatus.

Such a change is due either to a hiatus or a change in environment. I concluded this was not due to change in environment for the following reason.

From the cored section in the Naranjo tests, where the beds belonging to the interval of the hiatus were well represented, they took on the nature of an alternating series of gray shales typical of the San Felipe and white limestones typical of the Tamaulipas, not a nature of marked and abrupt change from one type to the other.

The fauna of these beds representing the hiatus was transitional. Had it been controlled by environment one would expect a concentration, at least to some appreciable extent, of Tamaulipas forms in the white limestone, and

of San Felipe forms in the gray shales. As this was quite contrary to the facts of the case, I concluded it was not a question of environmental change.

As this transition zone is not present in the producing tests, from which my field section was adopted by comparison, and as it was difficult to know how much of the transition properly belonged to either formation, its fauna was not shown in my work. Only those forms which ranged from above the transition zone to below it, not those ranging from Tamaulipas upward into it, were shown, because the Tamaulipas, for its own fauna, was not included.

Hiatuses elsewhere are known in which this transition zone is missing. In his present work, page 32, Muir states, "Since the foregoing was written, a conglomerate was observed (October, 1935) at the top of the Tamaulipas limestone."

In Table II, page 20, he shows a hiatus in the Southern oil fields and in the Sierra Del Abra section, above the El Abra which he states is the reef equivalent of the upper Tamaulipas limestone, and below the upper San Felipe or Agua Nueva, whichever applies to the section in question.

Muir also shows a variation in "depositional thickness," page 52, varying from 4 to 520 feet for the Agua Nueva, depending on relation to synclinal or anticlinal position in the producing areas.

The essential confinement of rich production to a slight interval in the San Felipe and to only a little greater interval in the Tamaulipas to either side of their contact or this hiatus is looked upon by me as evidence of the hiatus. This is especially notable when it is recalled that this part, the top of the Tamaulipas, is highly fissured, cavernous, and probably channeled, whereas the remainder is highly impervious.

I had assumed, and still believe, that the movements which created the productive structures, over which the hiatus occurs, antedate the building of the mountain ranges in which Muir's conformable relations are shown and before reaching which, from the direction of the producing "highs," I found the gap had been filled to give "conformable" relationships.

I suspect Muir's Agua Nueva, or at least the basal part where represented by greater thicknesses, is neither San Felipe nor Tamaulipas as treated by me, but this transitional section the fauna of which was not dealt with directly in my work.

M. P. White

Ardmore, Oklahoma
September 5, 1936

CORRECTION

On page 208 of *Geology of the Tampico Region, Mexico*, by John M. Muir, there is an inadvertent misstatement in the concluding sentence of the third new paragraph on the page. That statement should be:

"Production during December, 1934, amounted to 1,086,000 barrels from 246 stripping wells, or an average of 35,000 barrels per day."

On page 37, line 5 from bottom, "*Astieria* aff. *bachelardi* Sayn" should be *Astieria* (*Valanginites*) aff. *bachelardi* Sayn.

GRAPHIC METHOD FOR DETERMINING TRUE DIP FROM TWO COMPONENTS

Four years ago I described a graphical method for determining true dip from two components[1] which I had devised for use in structural work in southern New York where bedding is uniform, but recognizable key beds are generally lacking.

Recently, one of my students called attention to the fact that several years ago Professor G. D. Harris of Cornell University published the same method for determining true dip from two components in a little book—*Notes on the Elements of Geologic Mensuration*, second edition, Ithaca, New York, 1914—which he had printed for the use of his students.

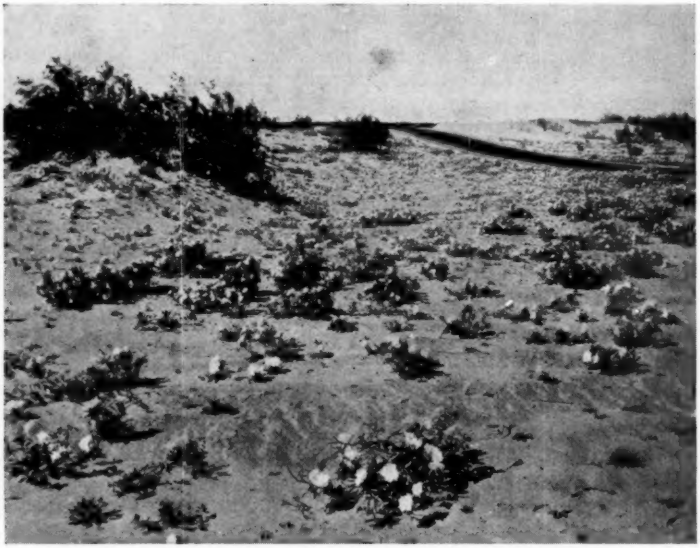
This note is written to give to Professor Harris credit for priority in devising the method. Harris writes:

> As to the little demonstration of dip, I worked out what I thought an easy scheme for my students to practice and in the end put it in print. Ten to one others had worked it out long before but I never took the trouble to see. I went at the problem just as you did.

JOHN L. RICH

UNIVERSITY OF CINCINNATI
October 9, 1936

[1] John L. Rich, "Simple Graphical Method for Determining True Dip from Two Components and Constructing Contoured Structural Maps from Dip Observations," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 16 (1932), pp. 92–94.



Desert flowers you will see enroute to Los Angeles.
(Annual meeting, March 17–19, 1937.)

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 20, NO. 11 (NOVEMBER, 1936), PP. 1497-1509

REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library and available to members and associates.

"La constitution géologique des Antilles." By L. BARRABÉ. *La Chronique des Mines Coloniales* (Paris), Vol. 5, No. 52 (July 1, 1936), pp. 214-27; 2 maps.

The Antilles of the title prove on inspection to comprise only the French Antilles, and chiefly the two larger ones, Guadeloupe and Martinique islands. In spite of this limitation, the paper is interesting as a record of original observations and also because the author points out the bearing of his observations upon the vexed questions of the age and history of the Lesser Antilles.

In his sketch of the geologic setting of the French Antilles Professor Barrabé adopts the "zones" of Suess: the inner volcanic zone of which Martinique is perhaps the best known member; the middle zone with the greater Antilles, Virgin Islands and some of the Lesser Antilles lying easterly from the volcanic members; and the external zone—Bahamas, Anegada, Sombrero and Barbuda—"in reality the prolongation of Florida," comprising low islands or banks with no formations older than Quaternary or latest Tertiary. Whatever interpretation we may adopt to explain the structure of the Archipelago, says Barrabé, this classification may well be retained.

Guadeloupe is composed of two islands separated by a narrow channel, the Rivière Salée. The high western island, dominantly volcanic, has in places outcrops of an Amphistegina limestone, apparently Miocene, which lies on older volcanics. The older volcanoes of the post-Miocene period are judged to be Pliocene or Quaternary.

The eastern member of Guadeloupe, called Grande Terre, is relatively low and is composed of several plateaux of different height. Most of the limestones exposed are coral reefs, and the majority are definitely Aquitanian in age, though a few probably Pliocene and Quaternary exposures occur, the latter not more then 10 meters above sea-level. Some Miocene sands and tuffs are also found.

The small islands near Guadeloupe, including Marie-Galante, La Désirade, and Petite-Terre are generally similar to Grande-Terre, though not without interesting peculiarities. Thus La Désirade has a higher plateau, tilted noticeably to the northeast, and a basement with granodiorite and schist.

Unlike Guadeloupe and its dependencies the island of Martinique belongs wholly to the inner (volcanic) zone. Marine sedimentary formations—including both Aquitanian and Burdigalian representatives—are found only along the south and east coasts where they lie on pre-Aquitanian volcanic formations. They are gently folded along axes striking west-southwest and east-northeast. The later volcanoes are younger toward the north, and their products more basic. Mount Pelee is still active.

On the problem of the origin of the Lesser Antilles, Professor Barrabé disagrees mildly with Professor Schuchert's idea as to the extreme youth of the volcanic Caribbees. His summary of their history may be paraphrased as follows. Upon a granodioritic eruptive socle, age unknown but probably

Upper Cretaceous or Lower Eocene, both the inner and middle axes of the Lesser Antilles were established at the beginning of the Tertiary. A partial cessation of eruptive activities, correlated with a submergence of the ancient socle, took place in the Lower Miocene and permitted the deposition of locally thick marine detrital sediments and limestones. Toward the end of this period of submergence there was renewed volcanic activity, localized this time in the inner arc. Gentle folds developed, probably in Upper Miocene, the strike being west-southwest and east-northeast on Martinique and west-northwest and east-southeast on Guadeloupe. Since this epoch the French Antilles seem not to have undergone any important vicissitudes. Volcanoes along the border of the Caribbean have erupted occasionally during the whole time, and old shore lines have been raised and lowered and some of them notably tilted.

RALPH D. REED

PASADENA, CALIFORNIA
September, 1936

**Rotary Drilling Handbook*. By JOHN EDWARD BRANTLY. Russell Palmer, Los Angeles (1936). 304 pp., 45 illus., many tables and formulas. 5.25×7.5 inches. Flexible cover. Price, $3.50.

Rotary Drilling Handbook is the first book devoted exclusively to drilling oil and gas wells. It will be of value to anyone interested in rotary drilling regardless of how much or how little he may know of the subject.

Brantly's active rotary experience has been in California and naturally he writes with some California accent. Even so, there are few points in his discussion that are not equally applicable wherever there is deep rotary drilling. The text is a description of rotary equipment capable of drilling the deeper wells, but it is more than mere description. The qualities and types of each class of equipment are given on which an operator bases his selection of the particular type or piece of equipment for the drilling job at hand. The experienced driller will find many of his present ideas concretely stated, and among them several new ones worthy of his consideration. There is little discussion of the art of drilling—certainly intentional—probably wise.

Brantly has introduced several new practices in drilling and dwells on these at considerable length—more than their general field application would at this time justify. Perhaps the book is, to this extent, ahead of its time.

The text covers 200 pages. It is followed by a glossary of terms and definitions of terms used in the text. It is too brief. While inclusion of such terms as "water table," "crown block," and "rat hole" might seem superfluous to the driller for whom the book was primarily written, they would be of as much value to many as, for example, "diameter."

Seventy-five pages are filled with tables, formulas, and curves. They are all in terms and units in common use in the oil fields. Many of them contain data not obtainable elsewhere, such as amount of various solid materials required to obtain a given weight rotary mud. Others have information which is available but too often not when it is needed. Some are common to almost any book or booklet for field use. This section is valuable to anyone having anything to do with rotary drilling.

The book is written in easily readable language. It is technical enough to be of value to the engineer, practical enough to be of value to the driller or

operator, and at the same time understandable by one not so intimately familiar with rotary equipment and drilling.

C. V. MILLIKAN

TULSA, OKLAHOMA
September 30, 1936

Naphthene and Methane Oils, Their Geological Occurrence and Origin. By HANS HLAUSCHECK. Published by Ferdinand Enke, Stuttgart, Germany (1936).

The writer has made a study of the relation between the chemical base of crude oils and the geological conditions under which they are found, basing his observations on several hundred published analyses of Polish and Roumanian oils. The other oil regions have been treated in a cursory way only. The question of source rocks of the Carpathian oil fields has received due consideration. The writer believes he has proved that the oil of the Carpathian Flysch originated in the Flysch, and that the naphthene oil of the Roumanian Dacic (Upper Pliocene) had its source above the Meotic (base of Pliocene). The methane oil of the Meotic is very probably indigenous to this formation although a deeper origin can not be considered as impossible.

These regional studies have led to some general ideas which are outlined in the following paragraphs. For particulars the reader is referred to the book which will be published by Ferdinand Enke, Stuttgart, Germany, this fall.

It can be shown that two general rules are well established.

Rule I. Nearly all crude oils found so far in Paleozoic beds are of methane base. Among oils of the Tertiary, naphthene oils are predominant.

Rule II. In separate Tertiary basins the crudes in the older formations tend to be methanic in character while in the younger beds of the same basin, oils with higher naphthene content are to be found.

Essentially, both rules are not new, but an historical treatment is not attempted here.

Most theories on origin of oil, especially when brought forward by chemists, do not take into consideration these two important rules, and this is one of the main reasons why none of these hypotheses appealed to the geologist. On the other hand, geologists have tried to build their own theories on oil genesis, but the result, in most cases, did not win the approval of the chemists.

There are only two theories which take into consideration the rules as formulated.

One thought is that the "protopetroleum" was paraffinic in nature in all cases; that oil was formed at the depth of about 4,000 meters; that the naphthene oils now common in the beds nearer the surface have been altered during their upward migration by the influence of factors linked with the surface; and that methane oils have been converted into naphthene oils by oxidation. This is essentially Krejci-Graf's "Hut-theorie" which gained some followers, especially in Germany, during the last few years.

Höfer, impressed by the facts which led to the establishment of Rule I, believed that the protopetroleum is naphthenic, and that paraffine oils are the result of an aging process accelerated by heat and pressure. However, he did not venture to explain the chemical details of this process. This has been done in the last few years by Wallace E. Pratt and Donald C. Barton who believe that by hydrogenation the naphthenes of the protopetroleum could

be converted into paraffines, the necessary hydrogen being supplied probably by methane gas. According to these two authors the naphthenic protopetroleum has been formed near the surface at temperatures of less than 80°C.

A critical review of these hypotheses shows that the "Hut-theorie" can be dismissed at once because oxidation of paraffines to naphthenes is a reaction wholly unknown to modern chemistry, and because there is no geological reason to believe that nature is hiding such a process which chemists have failed to detect. The existence of oil accumulations rich in paraffine-hydrocarbons at shallow depths and the existence of naphthene oils at much greater depths is a further proof against this hypothesis.

The hydrogenation theory has a much better basis, and its possibility must be admitted. There are, however, several facts which do not fit well into this concept: (1) most crude oils contain certain components which should have been destroyed or altered by hydrogenation; (2) whether non-biological hydrogenation proceeds at low temperatures is not known, and should not be assumed without further proof; (3) the relation between age and degree of hydrogenation should be much closer than it really is, if only such general factors as time, heat, pressure, and the availability of methane gas are to be of influence.

The writer's own opinion about the distribution and genesis of oils of different chemical character is based on the fact that the source material of oil consists first, of material which originated in the sea and second, of material brought into the sea by certain rivers. This latter material consists mainly of lignin substances and derivatives thereof (humines) which have been shown to have essentially a cyclic character while the organisms of the sea are built up from compounds of the chain type. Lignin and its relatives exist in greater amounts in the higher organized terrestrial plants, and form the only rich source of cyclic hydrocarbons. Plants of low organism contain only traces and small amounts of lignin, and the same can therefore be safely assumed to be valid for Paleozoic plants. In Paleozoic time the main source of cyclic hydrocarbons was very poor, just beginning to develop; therefore, its oils are poor in cyclic hydrocarbons. Rule I is the reflection of the chemical development of terrestrial plants.

Therefore, a relation between the chemistry of the material (richness in cyclic compounds) gathering on the bottom of the sea and the "influence" of the land has been made probable. The nearer the coast the better the chance for the concentration of cyclic hydrocarbons in the accumulating sediments. In most Tertiary basins the younger beds have been formed in shallower waters, nearer the coast than the older beds. In fact, the essence of the geological history of many Tertiary basins is the emergence ("Verlandung") of gulfs, bays, and marine basins. No wonder, therefore, that the source material accumulating in the younger beds is more under the influence of the land, and therefore receives more cyclic compounds (lignin, humidic substances) than have the older sediments. Rule II shows the evergrowing influence of the land on the source material due to the filling of the basin.

Besides this "Humin hypothesis" there is another set of facts which could explain the relation expressed in Rule II. It is well known to chemists that highly unsaturated fats and fatty acids have a greater tendency to form cyclic compounds than saturated or nearly saturated fats. By lowering the temperature, organisms can be induced to form fats and fatty acids of a lower degree

of saturation. The colder the climate the more unsaturated fats are built up by the organisms, and the greater is the probability of a source material rich in cyclic compounds. The climate during Tertiary time had been growing colder and colder, and during the Quaternary the ice sheet was only 1,000 kilometers north of the Gulf Coast of Texas and Louisiana. Therefore, Pliocene marine life formed a source material richer in cyclic hydrocarbons than did Eocene or Oligocene organisms.

The writer believes he has shown that the theory of a deep origin of petroleum—about 4,000 meters—is not consistent with chemical and geological observations, and that its formation rather close to the surface at temperatures well below 100°C. is much more probable.

HANS HLAUSCHECK

PRAGUE, CZECHOSLOVAKIA
August 28, 1936

Petroleum Technology, 1935. The Institution of Petroleum Technologists, Special Publication. 260 pages. Published by the Institution, Aldine House, Bedford Street, London W.C. 2. Price, 7/6 net.

Since the year 1924 it has been the custom of the Institution of Petroleum Technologists to publish in its *Journal*, annually, a review of the advancements made in petroleum technology during the preceding year. This review for the year 1935 appears in a separate book called *Petroleum Technology, 1935*. The American Institute of Mining and Metallurgical Engineers publishes each year a similar review of progress in the petroleum industry known as *Petroleum Development and Technology*. A review of *Petroleum Development and Technology, 1936* (covering the year 1935) appeared in the September number of this *Bulletin* (Vol. 20, No. 9, p. 1258).

It would be natural to anticipate that these two reviews must duplicate each other to a considerable degree, unless the respective authors adhered to a deliberate "division of labor" in their preparation. Remarkably enough, then, the reviewer finds neither extensive duplication nor any evidence that either publisher has consciously excluded any part of the field for review in the two reports for the year 1935.

The explanation of this anomaly lies in the widely different methods of approach employed by the two enterprises. The members of the American Institute appear to view petroleum technology as their own field; they divide it up geographically or functionally and each author appropriates to himself his particular area or subject for authoritative, first-hand treatment. In many cases he writes out of his own experience. The Institution of Petroleum Technologists, dominantly British in character, maintains a scrupulously impersonal attitude and examines in detached fashion the accomplishment of workers in the several operations of the petroleum industry. Theirs is a review of the literature of petroleum technology during the preceding year. These viewpoints are so distinct that few readers of these two books will complain of duplication of effort.

Let no one conclude, however, that the British review of petroleum technology fails to keep fully abreast with progress in the industry. The observations which found their way into the papers covering the year 1935 are discriminating and pertinent. They reveal an enviable alertness on the part of

the authors, and in them are to be found implications of those movements and developments which came to be important as the year 1936 drew on.

Petroleum Technology, 1935 is a series of twenty-four papers, edited with unusual care, and admirably selected, arranged, and indexed. Especially to be commended are the impressive lists of references, or bibliographies, which accompany each paper. The editorial work as well as the collection and arrangement of the articles fell to the lot of the Abstracts Sub-Committee of the Institution, under the chairmanship of F. H. Garner. One striking contrast between *Petroleum Technology, 1935* and *Petroleum Development and Technology, 1936* is the greater breadth, or range, of subject matter which the former covers. In America such subjects as "Aero Engines" have commanded more attention in the past from automotive engineers than from petroleum technologists. Refining processes, chemistry of petroleum, and substitute sources of liquid fuels and lubricants are accorded greater emphasis than petroleum technologists in general are wont to give them in America. Nevertheless, the review also treats rather fully petroleum geology, including geophysics, drilling methods, production technique, natural gas and gasoline, special products, and petroleum statistics.

To American readers there is a certain naiveté in the style of *Petroleum Technology*. It is revealed in the mental attitude which makes it possible for its editors in all seriousness to present a summary of the results of exploration efforts during the past year under the rather comprehensive title, "Geology of the Oilfields," and to fail to detect so glaring an error as the statement (page 7) that "the annual consumption (of the United States) now approaches 100 million barrels." American readers will also find themselves stumbling over unaccustomed spelling and usage, such as "kerosine" for kerosene, "benzole" for benzol, "carburettor" for carburetor, and "airscrew" for propeller.

Progress in geophysics, drilling practice, and production methods, as it is revealed in current literature, is adequately reviewed. The existing state of these techniques in the United States receives first attention, as may perhaps be justified by the relative volume of its output, but other producing and prospective areas are not slighted. It is probably inevitable under the circumstances that details in perfecting the actual methods of geophysical exploration should escape notice in a review of this character. The lag between accomplishment, itself, and the revelation of accomplishment to the general public is still too great to permit current advances to be recorded in current reviews. The remarkable increase in speed of drilling and the use of the gun-perforator in production practice also escape mention.

Refining in France is reviewed briefly but understandingly. The tendency toward increased capacity in refining in France has already had a material effect on the industry in America. In spite of the fact that the volume of products from French refineries more than doubled from 1933 to 1935, it is not anticipated that further refinery construction will be undertaken. Refining (charging) capacity is now of the order of 6,000,000 tons annually whereas home consumption is barely 4,000,000 tons. There is no incentive, therefore, to expand further.

Outside of the "Review of Petroleum Literature" by Winifred S. E. Clarke, the most ambitious papers in the series are, perhaps, "Chemical and Physical Refining" by G. R. Nixon, and "Cracking" by Gustav Egloff and

others. Both are informative and comprehensive. Egloff's carefully written paper is excellent. "Lubricants and Lubrication" by W. E. J. Broom, reviews at length the year's study and accomplishment in perfecting the "oiliness" of lubricants, particularly the results of solvent-extraction processes. "Chemistry of Petroleum" by B. C. Allibone and "Low Temperature Carbonization and Retortable Oil-Yielding Materials" by W. H. Cadman are both imposing papers. The paper by C. Chilvers on "Special Products" deserves careful reading. All of the papers on refining methods find it necessary to speak often of polymerization, solvent-extraction, and vapor-phase cracking in describing advances in refining technique in 1935. Polymerization has made possible among other things the production of 100-octane gasoline on a commercial basis. Polymerization comes in for special mention again in Hoffman's discussion of "Natural Gas, Natural Gasoline and Liquified Petroleum Gases," in 1935, and in "Light Distillates, White Spirits and Kerosine" by R. J. Evans.

In "Aero Engines," H. B. Taylor describes British airplane motors in detail with excellent illustrations. He believes that airplanes are likely to continue to be gasoline-driven. With 100-octane gasoline just around the corner, practically all development of the compression-ignition type of engine for airplanes is at a standstill. This statement may give pause to some of our enthusiasts who see Diesel-motor fuel entirely supplanting gasoline in the near future.

Cadman's splendid paper on "Low-Temperature Carbonization and Retortable Oil-Yielding Materials" will impress on the casual reader the fact that in spite of liberal government subsidy, the problem of "oil from coal" is as yet far from solved.

"Statistics" by George Sell includes figures for world-wide production of crude oil, natural gas, asphalt, and oil shale by countries over a period of years. For the United Kingdom more details are made available.

The paper of outstanding interest to petroleum geologists is Professor V. C. Illing's concise "Geology of Petroleum." Touching on the origin of oil he sees weighty objections to David White's theory that pressure and temperature over a long time metamorphose organic matter into oil, or that pressure and temperature combined produce over long periods reactions which normally require much higher temperatures. He points out the conflict in White's denial that oil forms soon after sediments are deposited and Levorsen's view that oil is formed in a basin of sedimentation and guided by forces of compaction to areas of concentration. The difficulty in the way of oil forming in a sediment is to prove that high-molecular-weight hydrocarbons are produced by biochemical action. Professor Illing would await such proof before accepting such an origin for oil. Treib's startling claim that chlorophyll can be identified in many crudes as constituents that could not have been subjected to temperatures greater than 200° C. at any time is appropriately brought to the reader's notice and Barton's work on the stratigraphic occurrence of different crudes in the Gulf Coast is commended.

Both *Petroleum Technology* and its American analogue, *Petroleum Development and Technology*, recognize the widespread interest of the petroleum industry in the recent date of discovery of petroleum reserves. Yet neither publication succeeds in bringing any light to bear on the subject. To the reviewer this is a notable omission. The petroleum industry will probably not be

content to continue so far to ignore the results of its oil-finding effort that important annual reviews of its progress can go to press devoid of any significant figures on discovery rates.

WALLACE E. PRATT

HOUSTON, TEXAS
October 12, 1936

Erdöl. By K. KREJCI-GRAF. 28th volume of a series on popular science. 164 pp., 30 figs. Published by Julius Springer, Berlin (1936). Cloth-bound. Price, RM 4.80.

This book is primarily written for the layman. Although it is devoted in a large degree to discussing the fundamentals of oil geology it contains much information of interest to the professional man. This is particularly true of the chapter discussing the various theories concerning the origin of oil. The author advocates the theory of organic origin, basing it, to a great extent, upon the presence in oil of small traces of derivates of chlorophyll and haemin, of cholesterin and other substances which can only have been derived from organisms. Certain delicate substances found in oil indicate that the formation must have taken place under moderate temperatures, not exceeding 250° C.

The author contends that oil was primarily formed in sediments covered by water free from oxygen. The source material is found in the organisms floating in the upper strata of the ocean. The dead bodies which fall to the bottom of the sea are transformed by anaërobic bacteria, specimens of which have been found, according to Krejci-Graf, in oil-field waters and in source rocks. Particularly favorable for the formation of petroleum are conditions like those existing in the Black Sea, where poisonous water, that is, water free from oxygen and containing hydrogen sulphide, is found at a comparatively shallow depth, thus permitting a great percentage of the dead organisms to reach the protecting hydrogen sulphide water before being destroyed by oxygen. The transformation of organic substances into hydrocarbons is thought to take place soon after deposition inasmuch as samples taken from the bottom of the Black Sea contain some yellow oily and white vaseline-like matter.

The water associated with the oil is considered to be not merely condensed sea water but to be derived from the organic material buried at the sea bottom. This theory is based chiefly on the difference in composition of the oil-field water and the sea water and, particularly, on the high content in the former of iodine and bromine.

While the book is, in many ways, very interesting and thought provoking, it loses some of its value by occasional inconsistencies and generalizations incompatible with conditions in many of the American oil fields. On page 118 the author states, for example, that the surprising feature of oil-field waters found in sweet-water deposits is their content of iodine and bromine, while, on page 119, he mentions that the high content of these and other elements prove the oil-field water to be derivates from sea deposits. Rather surprising is the statement on page 152 that it is almost impossible to recognize geological horizons from rotary returns.

For a geologist familiar with the large oil deposits in many of the blanket sands in the Mid-Continent (Woodbine, Wilcox) it is difficult to subscribe to the comparatively small importance attributed in his book to lateral migration and to the great rôle stipulated for vertical migration. Somewhat unfortunate

is, in this connection, his use of the Oklahoma City oil field as an illustration of this theory inasmuch as the oil (aside from negligible quantities in the Cleveland sand) is entirely confined to one level, which cuts below the basal Pennsylvanian unconformity through the upper Arbuckle and Simpson formations, thus revealing no appreciable signs of vertical migration into the numerous upper sands of the Pennsylvanian. Furthermore, the bulk of the oil comes from blanket sands under conditions strongly suggesting extensive lateral migration, while the more lenticular Pennsylvanian sands above are mostly barren of hydrocarbons.

As a whole, the book is well worth reading, although it leaves the reader with the impression that many statements and generalizations should be taken with a grain of salt.

R. W. BRAUCHLI

OKLAHOMA CITY, OKLAHOMA
October 19, 1936

RECENT PUBLICATIONS

ALGERIA

*"Geology in the Coastal Atlas of Western Algeria," by Robert van Vleck Anderson. *Geol. Soc. America* (New York) *Memoir 4* (1936). 450 pp., 19 pls., 2 figs. In red buckram.

ENGLAND

*"The Carboniferous Succession in the Slaidburn District, Yorkshire," by D. Parkinson. *Quart. Jour. Geol. Soc. London* (London), Vol. 92, No. 367 (September 17, 1936), pp. 294–331; 1 fig., 3 pls.

FRANCE

*"Recherches de petrole dans le Jura méridional" (Search for Petroleum in Southern Jura Mountains), by Ch. Finaton. *Rev. Petrol.* (Paris), No. 703 (October 3, 1936), pp. 1479–82; 1 fig.

GENERAL

The Mineral Industry During 1935, Vol. 44, edited by G. A. Roush. McGraw-Hill Book Co., Inc., 330 W. 42nd St., New York (1936). 800 pp. 6×9 inches. Cloth. Price, $12.00. Covers statistics, technology, and trade for both domestic and foreign fields. Includes section on petroleum and petroleum products by Arthur Knapp.

*"Occurrence, Preparation and Utilization of Natural Carbon Dioxide," by J. Charles Miller. *Amer. Inst. Min. Met. Eng.* (New York) *Tech. Pub. 736* (September, 1936), 22 pp., 7 figs., 5 tables.

*"Assiniboine Great Sedimental Cycle," by Charles Keyes. *Pan-American Geol.* (Des Moines, Iowa), Vol. 66, No. 2 (September, 1936), pp. 113–36; 4 pls.

*"Petroleum Engineering Education—Present Curricula and Future Possibilities," by F. B. Plummer. *Min and Met.* (New York), Vol. 17, No. 358 (October, 1936), pp. 485–87; 2 tables. Tables give hours of credit in curricula offered in petroleum engineering and courses offered in departments of petroleum engineering in eight state universities.

*"The Economic Structure of the American Petroleum Industry," by Joseph E. Pogue. *Third World Power Conference* (Washington, 1936), Sec. 11, Paper No. 5. 47 pp., 15 figs., 4 tables.

*"Contribution a la genèse des gisements d'hydrocarbures" (Contribution to the Genesis of Deposits of Hydrocarbons), by Ch. Finaton. *Rev. Petrol.*, No. 704 (October 10, 1936), pp. 1509–14; 13 figs.

**General Alphabetical and Analytical Index*. Publications of the American Institute of Mining and Metallurgical Engineers (1926–1935). 431 pp. 6 x 9 inches. Cloth. Published by the Institute, 29 West 39th Street, New York City. Price, $5.00.

GERMANY

*"Die Entwicklung der Anschauungen über die Kalisalzvorkommen der Rheinebene" (The Development of the Views on the Occurrence of Potash Salt on the Rhine Plain), by Rudolf Wager. *Kali* (Halle—Saale, Germany), Vol. 30, No. 17 (September 1, 1936), pp. 161–65; 2 figs.

*"Ein magnetisches Profil durch Vorpommern" (A Magnetic Profile through Northwestern Pomerania), by S. von Bubnoff. *Geol. Rund.* (Stuttgart), Vol. 27, No. 4 (1936), pp. 365–80; 3 figs.

GULF REGION

*"New Upper Cretaceous Ostreidae from the Gulf Region," by Lloyd William Stephenson. *U. S. Geol. Survey* (Washington) *Prof. Paper 186-A* (1936). 8 pp., 3 pls. May be purchased from Supt. Documents, Govt. Printing Office, Washington, D. C.

ILLINOIS

A blue-line print, showing generalized cross section from north to south (Rockford to Cairo) and also from western to southeastern Illinois (Warsaw to Vincennes). *Illinois State Geol. Survey* (Urbana). Price, 65 cents.

A blue-line copy of the "Structural Map of Eastern Interior Basin." *Illinois State Geol. Survey* (Urbana), *Illinois Petroleum 27*, Pl. 1. Scale: about 15 miles to the inch. Price, 20 cents.

KANSAS

* "Disposal of Oil-Field Brines in the Arkansas River Drainage Area in Western Kansas," by C. J. Wilhelm, H. M. Thorne, and M. F. Pryor. *U. S. Bur. Mines Rept. Investig. 3318* (October, 1936). 28 mimeogr. pp., 3 figs.

MICHIGAN

*"Extent and Availability of Natural Gas Reserves in Michigan 'Stray' Sandstone Horizon of Central Michigan," by E. L. Rawlins and M. A. Schellhardt. *U. S. Bur. Mines, Rept. Invest. 3313* (July, 1936). 139 pp., 16 figs. Printed by Michigan Dept. Conservation in coöperation with Michigan Public Utilities Commission.

MONTANA

*"Revision of Type Cambrian Formations and Sections of Montana and Yellowstone National Park," by Charles Deiss. *Bull. Geol. Soc. America* (New York), Vol. 47, No. 8 (August 31, 1936), pp. 1257–1342; 10 figs., 2 pls.

MONTANA-NORTH DAKOTA

"Geologic and Structure Contour Map of the Cedar Creek Anticline, Dawson, Prairie, Wibaux, and Fallon Counties, Montana, and Bowman County, North Dakota. Scale, 1 inch—1 mile; structure contour interval, 50 feet. 2 sheets, each 53×25 inches. Price, 25 cents for set. May be purchased from Supt. Documents, Govt. Printing Office, Washington, D. C. Reprint of a map first issued in 1934, showing the areal and structural geology of the Cedar Creek or Baker-Glendive anticline, in eastern Montana and southwestern North Dakota.

NEW MEXICO

"The Mount Taylor Coal Field, New Mexico," by Charles B. Hunt. *U. S. Geol. Survey* (Washington, D. C.) *Bull. 860-B* (September 30, 1936). Accompanied by large geologic map and numerous sections of coal beds. Price, $1.00. May be purchased from Supt. Documents, Govt. Printing Office, Washington, D. C.

NORTH AMERICA

*"Geologic Literature on North America, 1785–1918," by J. M. Nickles. Part 1, Bibliography. *U. S. Geol. Survey Bull. 746* (1923; reprint 1936). 1,167 pp. Price, $1.25. May be purchased from Supt. Documents, Govt. Printing Office, Washington, D. C. A reprint of *Bull. 747*, which is the index to this volume, is now in press.

NOVA SCOTIA

*"Geology and Paleontology of the Georges Bank Canyons," Part I. "Geology," by Henry C. Stetson. *Bull. Geol. Soc. America* (New York), Vol. 47, No. 3 (March 31, 1936), pp. 339–66. Part II. "Upper Cretaceous Fossils from Georges Bank (including Species from Banquereau, Nova Scotia)," by Lloyd William Stephenson. *Ibid.*, pp. 367–410. Part III. "Cretaceous Bryozoan from Georges Bank," by R. S. Bassler. *Ibid.*, pp. 411–12. Part IV. "Cretaceous and Late Tertiary Foraminifera," by Joseph A. Cushman. *Ibid.*, pp. 413–40.

PENNSYLVANIA

*"Oil in Oriskany," by John P. Ruggles. *Oil Weekly*, Vol. 83, No. 2 (September 21, 1936), p. 43, 44, 46; 3 illus. Warren County discovery marks new era of activity in Pennsylvania.

*"Secondary Fault Found Present in Pennsylvania Gas Field," by T. P. Sanders. *Oil and Gas Jour.* (Tulsa), Vol. 35, No. 21 (October 8, 1936), p. 54; 3 illus., including geologic section showing major and secondary structures.

RUSSIA

*"Upper and Lower Boundary of the Middle Carboniferous Moscovian Stage," by S. V. Semichatov. *Amer. Jour. Sci.* (New Haven, Conn.), Ser. 5, Vol. 32, No. 189 (September, 1936), pp. 222–33; 3 tables.

TEXAS

"The Van Oil Field, Van Zandt County, Texas," by Ralph A. Liddle. *Univ. Texas Bur. Econ. Geol. Bull. 3601* (Austin). 79 pp., 27 pls. Price, $1.50. Frontispiece is a photograph of a model showing structural conditions on

Woodbine producing horizon. Seven maps of structural features of field on successively older formations from Midway to Lower Cretaceous. Other plates show regional structure, geologic sections, seismograph and torsion-balance data, and history and methods of development under unit management. Report is believed to afford most complete data available on any single oil field.

"The Jackson Group and the Catahoula and Oakville Formations in a Part of the Texas Gulf Coastal Plain," by B. Coleman Renick. *Ibid., Bull. 3619.* 101 pp., 10 pls. (including 2 geologic maps and 4 graphic geologic sections). Paper. Price. $1.00. In press.

"Geology of Texas," Vol. III—"Upper Paleozoic Ammonites and Fusulinids." Part 1—"Mississippian, Pennsylvanian, and Permian Ammonites," by F. B. Plummer and Gayle Scott; Part 2—"Permian Fusulinidae of Texas," by Carl O. Dunbar and John W. Skinner. *Ibid., Bull. 3701.* About 600 pp., 81 pls., 85 text figs. Cloth. Price, $4.00. In press. Two parts of this volume may be purchased as separates. Part 1—about 350 pp., 51 pls., 77 text figs. Paper. Price, $2.00. Part 2—about 250 pp., 40 pls., 8 text figs. Paper. Price, $1.75. Part 1 includes descriptions and illustrations of 161 species, including 63 genera, many of which are new. For purposes of comparison, sutures of all known Mississippian, Pennsylvanian, and Permian ammonite genotypes have been figured. Phylogeny of several families has been closely studied and authors have proposed important revisions in classification of ammonites. Part 2 gives special attention to adequate illustrations. Each species is illustrated by external views and by axial and sagittal sections and some by tangential sections. Remarkably large Permian fusulines are illlustrated on 6 double-size folded plates. Paper includes description of shell features and morphology of shell walls, a complete bibliography, a check list of 512 species and varieties, and a synopsis of the families and genera of Fusulinidae. Fifty-one species are described, most of which are new. All species known from Permian of Texas are included.

*"Outstanding Features of South Texas Geology," by George R. Pinkley. *Oil Weekly* (Houston), Vol. 83, No. 3 (September 28, 1936), pp. 51–53, 56, 58, 60; 8 figs. Numerous types of structures, multiple sands, and deep producing possibilities.

WEST VIRGINIA

*"Petrography of Oriskany and Corniferous Sands in West Virginia," by James H. C. Martens. *Oil and Gas Jour.* (Tulsa), Vol. 35, No. 20 (October 1, 1936), pp. 21, 23; 1 map.

"Deep-Well Records," by Rietz C. Tucker. *West Virginia Geol. Survey* (Morgantown, 1936). Logs of 550 wells in West Virginia and bordering states. Map of Charleston Quadrangle and isopachs of Devonian shales. 577 pp. Price: $2.00 in West Virginia; $2.04 outside.

ASSOCIATION DIVISION OF PALEONTOLOGY AND MINERALOGY

**Journal of Paleontology* (Fort Worth, Texas), Vol. 10, No. 6 (September, 1936).

"Recent and Fossil Pedicellariae," by H. L. Geis.

"Cretaceous Echinoids from Trans-Pecos Texas," by Jerome S. Smiser.

"Some Mid-Pennsylvanian Invertebrates from Kansas and Oklahoma: III. Cephalopoda," by Norman D. Newell.

"A Species of the Ammonoid Genus *Artinskia* from the Lower Permian of Kansas," by A. K. Miller.

"Middle Eocene Foraminifera from the Llajas Formation, Ventura County, California," by J. A. Cushman and J. H. McMasters.

"A Fossiliferous Horizon from the Lower Permian of Caddo County, Oklahoma," by R. W. Harris and Frank Worrell.

"Notes on Paleozoic Gastropoda," by J. Brookes Knight.

**Journal of Paleontology* (Forth Worth, Texas), Vol. 10, No. 7 (October, 1936).

"Revision of the Primitiidae and Beyrichiidae, with New Ostracoda from the Lower Devonian of Pennsylvania," by Frank McKim Swartz.

"Lower Permian Fusulinids from Sumatra," by M. L. Thompson.

"Lichadian Trilobites," by Fred B. Phleger, Jr.

"New Genera and Species of Ozarkian and Canadian Brachiopods," by Edward O. Ulrich and G. Arthur Cooper.

"A Timanites from Upper Devonian Beds of America," by A. K. Miller and P. S. Warren.

"Evidences of Insect Activity Preserved in Fossil Wood," by Charles T. Brues.

"A New Ruminant from the Hemphill Middle Pliocene of Texas," by R. A. Stirton.

"The Ilio-Sacral Attachment of Eryops," by Everett Claire Olson.

"The Systematic Position of Trachodon," by C. M. Sternberg.

"Upper Devonian Fish from Colorado," by William L. Bryant and J. Harlan Johnson.

"Footprints in Late Paleozoic Red Beds near Boulder, Colorado," by W. C. Toepelman and H. G. Rodeck.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 20, NO. 11 (NOVEMBER, 1936), PP. 1510-1522

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election, but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

FOR ACTIVE MEMBERSHIP

Daniel Martin Bernt, Jr., Los Angeles, Calif.
N. A. Rousselot, Frank A. Morgan, H. J. Steiny
Thomas Francis Grimsdale, Trinidad, B. W. I.
Cecil Drake, William A. Baker, Jr., W. Hegwein
Milton William Lewis, Los Angeles, Calif.
E. K. Soper, Frank Rieber, R. W. Sherman
Ben E. Lindsly, Washington, D. C.
Walter E. Hopper, Frank A. Herald, L. L. Foley
Gerald Francis Loughlin, Washington, D. C.
W. C. Mendenhall, Frank R. Clark, Hugh D. Miser
Robert H. Miller, Bakersfield, Calif.
Kenneth L. Gow, R. E. Drake, James L. Dorrance
Walter Sumner, Burnley, Lancs., England
F. E. Vaughan, M. G. Edwards, Leslie M. Clark
Raymond Victor Whetsel, Tampico, Mexico
John M. Muir, L. C. Snider, V. R. Garfias
Guillermo Zuloaga, Caracas, Venezuela
Pedro I. Aguerrevere, L. Kehrer, Santiago E. Aguerrevere

FOR ASSOCIATE MEMBERSHIP

Byron Warren Beebe, Tulsa, Okla.
Leo R. Fortier, Walter A. VerWiebe, Clark Millison
George Vincent Cohee, Urbana, Ill.
M. M. Leighton, Alfred H. Bell, Frank W. DeWolf
David Morgan Evans, Midland, Tex.
Cary P. Butcher, Richard E. Gile, Alden S. Donnelly
Orval Hall Hill, Tulsa, Okla.
Sherwood Buckstaff, Fanny Carter Edson, Clark Millison
Frank Walker Johnson, Maracaibo, Venezuela, S. A.
E. S. Neal, J. L. Kalb, E. F. Schramm
Harry Kilian, Lake Charles, La.
R. B. Grigsby, Garland O. Grigsby, C. I. Alexander
Roger Sylvis Mahoney, Ciudad Bolivar, Venezuela, S. A.
Philip Andrews, E. E. Brossard, P. E. Nolan
Harold D. McGlasson, Lake Charles, La.
J. M. Vetter, R. B. Grigsby, Garland O. Grigsby
Donald McCreery Oliver, Midland, Tex.
Paul A. Schlosser, Richard E. Gile, Cary P. Butcher
James Russell Reeves, Enid, Okla.
J. David Hedley, George I. McFerron, E. A. Markley
Andrew J. Rogers, Tulsa, Okla.
R. E. Shutt, W. C. Bean, Clark Millison
Olai Ingolf Torkelsen, Los Angeles, Calif.
Frank Rieber, E. K. Soper, Wayne M. Smith

FOR TRANSFER TO ACTIVE MEMBERSHIP

Lee H. Cornell, Wichita, Kan.
Roy H. Hall, Walter W. Larsh, George H. Norton
Charles Howard Dresbach, Pittsburgh, Pa.
E. A. Eckhardt, K. C. Heald, R. W. Clark
Vincent Evans, Oklahoma City, Okla.
Willard L. Miller, Hubert E. Bale, Albert S. Clinkscales
Frank Joseph Pospisil, Maracaibo, Venezuela, S. A.
E. S. Neal, J. L. Kalb, C. A. Baird
Garvin Lawrence Taylor, Wichita, Kan.
George H. Norton, Walter W. Larsh, F. E. Wimbish

TWENTY-SECOND ANNUAL MEETING, LOS ANGELES, MARCH, 17, 18, 19, 1937

The twenty-second annual convention of the Association will probably be the largest A.A.P.G. meeting held to date in California. The place is the Biltmore Hotel, Los Angeles, and the time Wednesday, Thursday, and Friday, March 17, 18, and 19, 1937. President R. D. Reed has announced some of the plans on his recent visits to the Rocky Mountain, Mid-Continent, and Gulf Coast geological societies. General chairman Frank A. Morgan gives the following preliminary list of committees and chairmen.

General chairman	Frank A. Morgan, Rio Grande Oil Company
General committee	C. R. McCollom, consultant
	G. C. Gester, Standard Oil Company (San Francisco)
	Vernon L. King
	R. W. Sherman, Standard Oil Company (Venezuela)
	R. S. McFarland, Seaboard Oil Company (Dallas)
	W. B. Heroy, Consolidated Oil Company (New York)
	Frank R. Clark, Ohio Oil Company (Tulsa)
Technical sessions	H. W. Hoots, Union Oil Company
Finance	A. A. Curtice
Entertainment	Richard G. Reese, Standard Oil Company
Publicity and exhibits	Roy M. Barnes, Continental Oil Company
Hotels	Earl B. Noble, Union Oil Company
Registration	J. E. Elliott, Elliott Core Drilling Company
Field trips	W. S. W. Kew, Standard Oil Company
Transportation	H. J. Steiny, Associated Oil Company
Golf	Angus McLeod, Shell Oil Company
Reception	E. F. Davis, Shell Oil Company

Harold Hoots, chairman of the program committee, has released the following statement.

All members of the Association should begin now to plan their attendance at the twenty-second annual convention of the Association to be held in Los Angeles March 17–19, 1937. This statement is made by the program committee because present indications justify the statement that the technical program will be of such high calibre as to encourage the attendance of members throughout the United States.

The technical program will consist of papers dealing with all districts of the United States important for their present production and their future possibilities. Many regional problems facing the geologists of different districts and important fields within each district will be covered by papers delivered by men recognized as specialists on these subjects. Recent develop-

ments in all important districts will be covered in a brief, concise manner by a separate series of short papers.

The program committee responsible for thes election of papers and speakers from the various districts is composed as follows.

Chairman:	Harold W. Hoots	
Members:	A. I. Levorsen	Adviser-at-Large
	A. A. Baker	Washington, D.C.
	Monroe Cheney	Texas (except West Texas)
	Ira H. Cram	Oklahoma
	C. E. Dobbin	Rocky Mountain Region
	M. G. Edwards	California
	John F. Kinkel	Kansas
	E. Russell Lloyd	West Texas and New Mexico
	C. L. Moody	Louisiana and Arkansas

The combined efforts of these men, each of whom is to specialize on his own district, will assure a program which few members can afford to miss.

It is requested that members having papers in preparation for the technical program correspond directly with the above-mentioned program committee member for his district. Members in districts not mentioned in this list should correspond with the chairman of the committee regarding the submittal of papers for the technical program.

Typical California structures.

Titles and abstracts of manuscripts, with number and kind of illustrations to be used (maps, slides, *et cetera*) and time desired for presentation, should be sent to Harold W. Hoots, Union Oil Company, Los Angeles, California, before February 15.

SAN ANTONIO SECTION EIGHTH ANNUAL MEETING

The eighth annual mid-year meeting and field trip of the San Antonio Geological Society were held on October 16–18 in Laredo, Texas. On Friday, October 16, a field trip started at Pleasanton, in Atascosa County, 35 miles south of San Antonio, and terminated at Loma Vista, in Zavala County. On Saturday, a technical program was presented at Laredo and on Sunday, October 18, a second field conference started at Laredo and finished at Eagle Pass.

On Friday, 125 geologists in 51 cars met at 7 A.M. in front of the City Hall (old stone courthouse) in Pleasanton, Texas, well equipped with filled thermos jugs and lunches for a long day's session. Starting at Pleasanton, and in the vicinity thereof, contacts of the Queen City, Weches, Sparta, Stone City, and Crockett formations of the Claiborne were visited. From there the caravan journeyed westward through Jourdanton, Charlotte, and Hindes to Pearsall where a brief stop was made. Discussions during the early part of the trip were conducted by H. B. Stenzel of the Bureau of Economic Geology at Austin, George Clark of The Texas Company, Stuart Mossom of the Magnolia, and Willis Clark of the Amerada. A number of new recruits joined the party at the town of Pearsall and then proceeded westward to the Pearsall field in Frio County. A very enlightening view of the structural conditions of the Pearsall field was pointed out by Willis Clark and Oscar Champion from a high elevation to which the party was conducted. Various wells were visited in this field and many interesting side-lights regarding the structure and physical operations of the field were pointed out. The San Antonio Society feels deeply grateful to the Amerada Petroleum Corporation for its kindness and courtesy in doing this. At Loma Vista, in Zavala County, the trip ended at about 5:30 P.M. and the party proceeded to the main highway for a 125-mile drive to Laredo for the night.

Headquarters at Laredo were located at the Hamilton Hotel. About 200 geologists attended the technical session in the auditorium of the San Agustin School on Saturday. The program was well balanced and the papers were received with enthusiasm. Although the auditorium was some distance from the hotels, a fleet of taxicabs was available for members and guests.

ABSTRACTS OF PAPERS

1. Eocene Paleogeography of Southern California, by Ralph D. Reed, Los Angeles, California, president of the Association.

2. Correlation of the Claiborne of Southwest Texas with the East Texas Section. A Discussion by the Field Trip Committee, led by H. B. Stenzel, Austin, Texas.

A brief résumé of the East Texas Claiborne section is given, followed by a comparison of Claiborne formations encountered in wells through Bastrop, Gonzales, Wilson, Atascosa, and Frio counties. The East Texas section serves as a basis for a tentative correlation of the Claiborne section studied during the Friday field trip. Considerable detailed information is presented during the discussion of this problem to substantiate the correlation tentatively offered.

3. The Geology of the Chittim Anticline, Maverick County, Texas, by F. M. Plummer, Austin, Texas.

This paper discusses briefly the history of the geological work and oil developments in Maverick County. It describes briefly the stratigraphy and main features of structure of the Chittim anticline, refers briefly to the results of geophysical work, and points out some of the favorable features of the Maverick district which lead one to believe that a major oil pool may some day be developed.

4. The Stratigraphy and Structure of the Pearsall Field, Frio County, Texas, by Oscar Champion, Pearsall, Texas.

A history of the development of the Pearsall field is given. The stratigraphy of the Cretaceous section encountered by the wells at Pearsall is discussed and the correlation is made with the standard fault-line section. Structure contours are drawn on top of the Austin chalk.

5. Migration of Oil, by M. G. Cheney, Coleman, Texas.

The presence of oil in certain geologic traps and its absence in many others which at first appear favorable emphasizes the need of exhaustive studies of the controlling factors involved in the accumulation of oil. Comparison of productive and non-productive traps in areas where source beds appear alike leads toward certain deductions concerning migration of oil. These deductions must be checked against various observations and experimental evidence. Although contrary to some theories that have been widely held, it seems necessary to conclude that oil must experience a comparatively early origin and migration. Also that increasing overburden and compaction seem to be mainly responsible for migration of the oil into the reservoir. The lateral variation in thickness of overburden seems to be the main source of forces which cause and give direction to the movement of fluids within the reservoir. Provided conditions remain favorable there seems to be no need to proscribe limits as to distance of migration.

6. The Northeast Texas Fault Line, by Dilworth S. Hager, Dallas, Texas.

The fault line in northeast Texas is a continuation to the north and northeast of the Mexia-Powell line of faulting. In the most northerly counties the faulting increases in throw and grabens 2½ to 3 miles wide continue for a linear distance of 20 to 30 miles, or more. Production to-day along these faults has only been found in the Paluxy sand. Such production is located at Talco and Sulphur Bluff.

On Sunday morning, the 18th, at 9 A.M., 31 cars lined up near the site of the antimony smelter about 4 miles north of Laredo on Highway 2. Tom Buzzo of the Sun Oil Company conducted the first part of the trip and at various stops pointed out certain distinctive characteristics in the outcrops of the Yegua, Cook Mountain, and Mount Selman formations of the Claiborne. At Carrizo Springs, where the party stopped for lunch, F. M. Getzendaner took charge and piloted about 30 cars northwest toward Eagle Pass, studying outcrops of Carrizo, Wilcox, Midway, and the Upper Cretaceous.

The San Antonio Society was honored to have as its guests Ralph D. Reed, of The Texas Company, Los Angeles, president of the Association; C. E. Dobbin, with the United States Geological Survey, Denver, vice-president of the Association; A. I. Levorsen, of Tulsa, Oklahoma, past-president of the Association; Chas. H. Row, of the Sun Oil Company, San Antonio, secretary-treasurer of the Association; and a number of geologists from other states. Although the attendance was not so large as on other occasions, the interest and enthusiasm displayed appeared to be of a more serious nature.

A word here regarding the ladies. Originally this year's session was planned with headquarters at Eagle Pass and necessarily had to be changed on short notice due to a disastrous fire which ruined hotel accommodations there. In consequence of this change of plans on short notice it was found inconvenient to arrange any form of entertainment for the ladies and it was indeed with sincere regrets that such a course had to be followed. Consequently very few of the geologists' wives were present, and it is probable that this change of plans may have caused a great many geologists and their wives to refrain from coming who might otherwise have attended. However, through the courtesy of Mrs. Tom Buzzo an informal luncheon was arranged

Geologists on eighth annual field trip of San Antonio Geological Society, October, 1936.

for about 25 ladies at the Rendon Hotel at Nuevo Laredo. An informal dinner was held at the Plaza Hotel at 7 P.M., Saturday, presided over in a very able manner by Adolph Dovre, president of the San Antonio Society. Dovre called upon Ralph Reed and a few other geologists for brief talks, all of whom appeared to fall under the spell of our genial leader from Los Angeles, and it was unanimously agreed to accept his invitation to be entertained by his committee in Los Angeles next March at the annual meeting of the Association.

Much of the credit for this very successful affair is due to the efforts of Ed Porch and the field trip committee who spent many days in the field prior to the trip with H. B. Stenzel coördinating various individual ideas regarding the surface geology.

The officers of the San Antonio Society are: president, Adolph Dovre; vice-president, Wm. G. Kane; secretary-treasurer, Harry H. Nowlan; members of the executive committee, J. M. Dawson and W. K. Esgen.

Following are the committees responsible for the eighth annual meeting.

Field trip:	E. L. Porch, Jr., chairman	H. M. Fritts
	H. B. Stenzel	J. M. Hansell
	Stuart Mossom	Willis Clark
	Geo. H. Clark	F. M. Getzendaner
Program:	Wm. H. Spice, Jr., chairman	
	J. M. Dawson	
Transportation:	W. C. Weaver	

HARRY H. NOWLAN

AN EDITORIAL NOTE

The following note has been received from D. Dale Condit, Oil Search Limited, 350 George Street, Sydney, N.S.W., Australia, under date of September 1, 1936.

SUGGESTIONS TO AUTHORS

A survey of the titles of papers appearing in the *Bulletin* through the years reveals a great predominance of those dealing with Mid-Continent and Gulf Coast localities, occasional papers on Rocky Mountain and Pacific Coast areas, infrequent ones on other parts of the United States, a sprinkling of titles on foreign localities, and a fair leavening of papers on technical or theoretical subjects.

Members probably will agree that the ensemble effect has been reasonably satisfactory, perhaps with the reservation that, if there be any criticism, it is that too much space has been given to detailed description of stratigraphy in Kansas, Oklahoma, and Texas. Such material, though doubtless of surpassing interest to members occupied in those fields, is not always desired in such detail by others. There can, however, be no just grounds for complaint on that score considering that most members reside in that part of the country, and that they write for the edification of one another. Moreover, all of us, regardless of whether we follow our profession in Oklahoma, California, Canada, or Czechoslovakia, welcome informative papers on the varied modes of oil occurrence, interesting examples of which are so bountifully manifested in the fields of Kansas, Oklahoma, and Texas. There is no danger of devoting too much space to description of the less conventional modes of occurrence such as stressed in Levorsen's presidential address.

If there be any criticism regarding the average paper appearing in former years, it is that the style of presentation commonly followed has been such as would be appropriate only were all readers already more or less familiar with the district. Such is less and less true of late as the *Bulletin* attracts increased attention among students in all parts of the world. Through being less parochial in its style, the general interest of

a paper can be enhanced. For example, an index map showing general geographic and geologic relations frequently is helpful to those with no first-hand knowledge concerning an area. Also authors should bear in mind that, while names such as "Wilcox sand," "Atoka," "Edwards lime," *et cetera* may be household terms to a large number of readers who straightway visualize the position of each in the geologic scale, it is always best to err on the side of being over-explicit in defining geological names so as to avoid inconveniencing those unfamiliar with a region.

The above comments are prompted by remarks occasionally heard from geologists other than American in regard to the *Bulletin*. While expressing admiration and appreciation of the informative character of the publications of the Association, they remark on the provincial style of some papers which makes them difficult to follow.

As editor of the *Bulletin* I wish to express my appreciation to Mr. Condit for his interest in the *Bulletin* and his assistance in seeing ourselves as others see us, and my pleasure that such a frank statement is, in large part, commendatory. I hope that the following remarks reflect these feelings and that they will be taken as a sympathetic discussion of some of the points raised in the communication and not as a "reply" to Mr. Condit.

First, as to the distribution of papers by countries and areas. The editorial staff is subject to neither praise nor blame for any selection of areas or subjects to be represented in the *Bulletin*. For at least the past few years, the Association has been in a position probably not occupied by many similar organizations,—that of having more facilities for publication than material to publish.

The present editor has called attention in each of his annual reports to the facts that the *Bulletin* leads a hand-to-mouth existence so far as papers are concerned; and that grave doubts as to the material for next month's *Bulletin* have been felt not infrequently. Under these conditions, the editors have little opportunity of getting very far with plans for a properly balanced *Bulletin*, even if they felt that they were able to prescribe the proper balance. However, some effort along these lines is made. I remember soliciting Mr. Condit by letter for a paper on Australia with the excellent results shown in the August, 1936, *Bulletin*. We were also very glad to have the opportunity to publish several papers on foreign fields which were read at the Sixteenth Session of the International Geological Congress at Washington in 1934. At least a few of our members felt that possibly we were going too strongly toward foreign papers at that time, but the editorial staff would be relieved if a few more papers of the same quality were available at present.

It is believed that the preponderance of papers on Kansas, Oklahoma and Texas problems, and the detailed treatment given these problems, are explained fully, as Mr. Condit points out, by the distribution of our membership and the activity of exploration for petroleum in those areas. I can only agree with Mr. Condit that some papers on such subjects must appear "parochial" to readers not acquainted with the area:—that is, an acquaintance with the general conditions of stratigraphy and structure, and with the location of physical and cultural features, is assumed on the part of the readers, which, in fact, is had only by those already conversant with the area. However, the possible readers of such articles who do know the area in a general way probably far outnumber those who do not. It is questionable whether it is better to present papers in a form which may be difficult for those unacquainted with the area to follow or to burden a paper with material which is merely repetition of facts already known to the majority of possible readers.

If the *Bulletin* papers err it is certainly in the direction of omission. This is probably due principally to the background of the authors, but also to the fact that papers are submitted for critical reading (when there is time for such procedure) to those who are thought to be fully conversant with the area under consideration. Such readers are naturally not much more likely to notice the omission of locally well-known general information which would be of value to those who have done little or no work in the area than are the authors themselves. Also, it should be noted that, in many cases, papers must be sent to the printers by the business manager as soon as he receives them in order to get the *Bulletin* out on schedule. Opportunity is lacking under these circumstances for the editorial staff to make suggestions to authors, and for the authors to act upon them. This condition can be corrected only by having a greater supply of papers or reducing the amount of material published.

My personal preference is for each major article to stand independently and to include all information which will be of assistance to any geologist who may read it. I am a firm believer in the dictum which was strongly brought to my attention during my student days by R. D. Salisbury,—that scientific papers must be written not merely so they can be understood, but so they cannot be misunderstood. This is, of course, an ideal which, we will all grant, is very difficult to reach. Even with this ideal in mind as a general principle, there is always some hesitation in any particular case about asking an author to expand his contribution by adding material which to him is the already known basis from which he starts his investigation, and which is also known to most of those who will be interested in his paper, or at least is easily available in the literature. Too much repetition of general facts already known to them tend to discourage readers who would be interested in the details if they keep up their courage and get through to them. However, most authors will make no mistake if they write not less for the specialist but somewhat more for the geologist who has only a general knowledge of the area or the problem under consideration. This statement applies with particular force to the authors of papers on structural and stratigraphic problems.

The problems mentioned above,—as well as several others, such as drawing the boundaries between the field of petroleum geology on the one hand, and paleontology, mineralogy, petroleum engineering and petroleum economics on the other—resolve themselves into questions of balance between two desirable but mutually incompatible objectives. The performer on a tight-rope is not perpendicular to the rope very much of the time. He passes through the ideal perpendicular position only as he wobbles from one side to the other. I believe I can speak for the entire staff in denying any pretension to perfect perpendicularity in balance on *Bulletin* problems, and also in expressing the belief that somewhat better balance might be obtained if the staff were burdened with a somewhat longer and heavier balancing pole in the shape of more contributions.

Considerate criticism and suggestions such as those quoted above are certainly welcomed.

L. C. SNIDER

PACIFIC SECTION THIRTEENTH ANNUAL MEETING

The thirteenth annual meeting of the Pacific Section of the Association was held at the Biltmore Hotel, Los Angeles, California, November 5 and 6. Technical sessions were in the Music Room, North Galeria of the hotel, and an evening session in the Mona Lisa Restaurant. Chester Cassel, president of the Section, presided. The program was arranged by Louis N. Waterfall.

On Thursday evening, the Pacific Section of the Society of Economic Paleontologists and Mineralogists met in the Mona Lisa Restaurant to hear a paper on "Foraminiferal Faunule from the Vaqueros Formation of the Simi Valley, California," by L. W. LeRoy. The chairman of the program was W. F. Barbat.

The annual dinner-dance was enjoyed in the Rendezvous of the Biltmore on Friday evening.

Following is the list of technical papers with abstracts.

1. The Geology of San Nicolas Island, California, by Luis E. Kemnitzer.

The rocks forming San Nicolas Island are almost wholly composed of sandstones and shales, Middle Eocene in age. The island is elongate, with its major axis running N. 70° W. The submarine contours reflect a similar trend in a much larger mass and further indicate a rather extended uplift in a northwest direction toward Santa Rosa Island. San Nicolas Island is a high point on this uplift and the attitudes of the sedimentary series suggest that the island is the southeast end of an eroded and faulted anticline, with the anticlinal axis about one mile landward along the southwest shore, trending roughly northwest. The topography is in harmony with the folding, and the shape of the island is guided by the structure of the underlying sedimentary rocks. Five marine terraces above the one now being abraded show the successive stages in the carving of the island. The folding and faulting antedate the terracing, for the marine terraces cut across the beds disregarding structure. The terrace surfaces are not perceptibly warped and are nearly parallel to one another.

2. Notes on the Stratigraphy of the Sespe Creek-Piru Creek Area, by H. D. Hobson and W. D. Rankin.

A composite columnar ranging in age from Sespe to Pico (Pliocene) is built up, and lithologic and paleontologic correlations are made, tying together the various units of the district.

3. Geoelectric Exploration in the Tejon Ranch Area, California, by J. J. Jakosky and H. K. Armstrong.

The Tejon Ranch area discussed lies within the southern part of the San Joaquin Valley. Marine beds crop out around the border of the area, but the central portion is buried beneath thick continental deposits. Core holes and a few exploratory wells have been drilled while the remainder of the area has been explored by geoelectric work. The theory and operating technique of the electrical conductivity method employed in the geophysical work are given in detail. Comparison of results of drill holes with the geophysical predictions is given.

4. The Geology of the Eastern Half of the San Joaquin Hills, Orange County, California, by Francis D. Bode.

With the exception of the Pleistocene terrace deposits, all of the sedimentary rocks exposed in the San Joaquin Hills are Tertiary in age. The Tertiary section has a thickness of about 5,000 feet and is correlated with rocks of Sespe, Vaqueros, Topanga, San Onofre, and Puente formations. The dip of strata is thought to be largely due to the action of normal faulting, rather than folding. Basic lavas are found intruded as dikes along or near the planes of many of the larger faults. While the age relationship between the faulting and the intrusion is not clear, it is thought that they are in part contemporaneous and that both are, at least, pre-Pleistocene in age. It is suggested that the present topography of the hills has resulted from a gentle northward tilting of the area occurring in Pleistocene and Recent time

5. Connate Water in Oil Sands, by Howard C. Pyle.
Methods used for determining the fluid contents of sands will be described. Results of tests on cores from a Los Angeles Basin well indicate that approximately thirty-eight per cent of the pore space of oil sands which produce clean oil and gas is occupied by connate water. Probable reasons for the occurrence of this water are discussed.

6. Geological Causes of Poor Reflection Records, by Frank Rieber.
Clear-cut reflection records are obtained only with sharply defined, conformable bedding, of considerable lateral extent, uncomplicated by steep folding or faulting. Deviations from these conditions will give rise to waves returning from the earth from a number of directions at approximately the same time. Such multi-directional arrivals produce unsatisfactory reflection records on the usual visual seismograph record. A method is presented for overcoming these difficulties by analyzing the received vibrations and separating them into their component wave trains.

7. Progress of Geologic Branch of the California State Division of Mines, by Olaf P. Jenkins.
The Geologic Branch has issued eight publications this last biennium. It has five manuscripts on hand, and ten practically completed field investigations (most of which are contributions). A new bibliography for the five-year period, 1931–1935, is nearly ready for the printer. A revision of Bulletin 91. "Minerals of California," is in the making. A struggle has been made to issue a preliminary outline of the state geologic map this year. The plan is to publish altogether four state maps (scale 1:500,000): (1) Topography and first preliminary geologic map; (2) mineral deposits and second preliminary geologic map; (3) oil and gas fields, fossil localities, and third preliminary geologic map; and (4) Final colored geologic map. Each will be issued in six sheets, 27×42 inches.

7a. Migration of Oil Along Fault Zones, by Bruce L. Clark.

8. The Sycamore Canyon Formation, by Max L. Krueger.
The name "Sycamore Canyon formation" is suggested for a 3,800-foot interval of alternating conglomerates, sands, silts, and shales in the Whittier Hills. This interval has previously been described with the Fernando (Pliocene); its micro-fauna insures an Upper Miocene age for this interval. It is overlain by the Repetto formation (Lower Pliocene) and it is unconformably superjacent to the upper Puente member of the Puente formation, also of Upper Miocene age.

8a. Geology of the Outfall Sewer Tunnel, Palos Verde Hills, by J. R. Schultz.
A geologic section of the strata penetrated by the outfall sewer is discussed.

9. Relation of the Type Santa Margarita to the Type Monterey, California, by J. Edmund Eaton.

10. The Stratigraphy of the Tesla Quadrangle near Tracy, California, by Arthur S. Huey.
The gas discoveries at Tracy, McDonald Island, and Rio Vista have strengthened interest in the stratigraphy and structure of middle California. The Tesla Quadrangle lies west of Tracy in the Diablo Range. The post-Franciscan stratigraphy will be described with emphasis given to the Cretaceous and Eocene.

11. Eocene Paleogeography in Southern California, by Ralph D. Reed.
Recent stratigraphic studies have permitted the making of some new guesses about land and sea distribution and the changes that occurred from time to time between the end of the Cretaceous and the beginning of the Oligocene. The chief conclusions are: (1) that some large areas in the Coast Ranges were notably folded near the end of the Cretaceous; (2) that the tectonic provinces that existed throughout the Tertiary were defined by the post-Cretaceous folding; and (3) that upper Middle Eocene was the time of maximum transgression in the folded areas during the Lower Tertiary.

12. Geological Prospecting in New Guinea, by W. E. Heater.

13. "Art is Long and Time is Fleeting," by Harry R. Johnson.

SECOND WORLD PETROLEUM CONGRESS, PARIS JUNE 14–19, 1937

The second World Petroleum Congress is to be held in Paris, June 14–19, 1937. It is being organized by L'Association Française des Techniciens du Petrole, 44, Rue de Rennes, Paris, 6. The general secretary of the congress is J. Filhol, 85, Boulevard Montparnasse, Paris, 6. The section in which Association members are directly interested is the Section of Geology and Drilling, of which A. Galliot, State Counsellor, and Director General of the Bureau of Mines, is president, and H. de Cizancourt, of the French Association of Petroleum Technologists, is vice-president. This section plans to present a complete report for each oil-producing country, summarizing the exploitation activity by geology and geophysics. The scope of papers includes the following topics: (a) geological descriptions of petroliferous regions; (b) methods of geological prospecting, (1) surface work, air mapping, drilling, (2) laboratory, muds, microfauna, analyses, (3) synthetic studies; (c) drilling equipment, directional and deep drilling, spacing, control, flooding; (d) geophysics, (1) technical, (2) legislative. Besides the technical program, various excursions and entertainments are being arranged.

The executive committee specially requests members of the Association interested in attending, or contributing to, this congress to communicate with headquarters, Box 1852, Tulsa, now.

SEVENTEENTH INTERNATIONAL GEOLOGICAL CONGRESS, MOSCOW, AUGUST, 1937

The seventeenth session of the International Geological Congress has been announced to be held in Moscow, U. S. S. R., in August, 1937. The organization committee, I. M. Goubkin, chairman, Moscow, 10, U. S. S. R., Sretenka, 8, has issued two circulars. The first circular, dated January, 1935, listed the topics for discussion, as outlined in the *Bulletin* of June, 1935, pp. 935–36. The second circular, dated September, 1935, and printed, in part, in the *Bulletin* of December, 1935, pp. 1831–35, stated the scope of each subject. The nine topics are: (1) Problems of petroleum and petroleum resources of the world, (2) Coal fields, (3) Pre-Cambrian and its mineral deposits, (4) Permian system, (5) Tectonic processes, magmatic formations, and ore deposits, (6) Tectonic and geochemical problems of Asia, (7) Rare elements, (8) Geophysical methods, (9) History of geological science. Varied field excursions have been arranged before and after the session. The executive committee asks Association members who may attend the congress to notify headquarters, Box 1852, Tulsa, now.

ASSOCIATION COMMITTEES

EXECUTIVE COMMITTEE

RALPH D. REED, *chairman*, Los Angeles, California
CHAS. H. ROW, *secretary*, San Antonio, Texas
A. I. LEVORSEN, Tulsa, Oklahoma
C. E. DOBBIN, Denver, Colorado
L. C. SNIDER, New York, N.Y.

GENERAL BUSINESS COMMITTEE

ARTHUR A. BAKER (1938)
R. F. BAKER (1937)
WILLIAM A. BAKER (1937)
ROY M. BARNES (1937)
ROBERT L. CANNON (1937)
C. G. CARLSON (1938)
IRA H. CRAM (1937)
THORNTON DAVIS (1937)
FRANK W. DEWOLF (1937)
C. E. DOBBIN (1937)
J. BRIAN EBY (1938)
H. B. FUQUA (1937)
L. W. HENRY (1937)
HAROLD W. HOOTS (1938)
J. HARLAN JOHNSON (1937)
JAMES W. KISLING, JR. (1937)
A. I. LEVORSEN (1937)
THEODORE A. LINK (1937)
GERALD C. MADDOX (1937)
J. J. MAUCINI (1938)
JAMES G. MONTGOMERY, JR. (1937)
KENNETH DALE OWEN (1937)
RALPH D. REED (1938)
R. E. RETTGER (1938)
CHAS. H. ROW (1937)
G. W. SCHNEIDER (1937)
GAYLE SCOTT (1937)
E. F. SHEA (1937)
L. C. SNIDER (1937)
CLARE J. STAFFORD (1937)
J. D. THOMPSON, JR. (1938)
LOUIS N. WATERFALL (1937)
GERALD H. WESTBY (1937)
MAYNARD P. WHITE (1937)
NEIL H. WILLS (1937)

RESEARCH COMMITTEE

DONALD C. BARTON (1939), *chairman*, Humble Oil and Refining Company, Houston, Texas
HAROLD W. HOOTS (1939), *vice-chairman*, Union Oil Company, Los Angeles, California
M. G. CHENEY (1937), *vice-chairman*, Coleman, Texas

ROBERT H. DOTT (1937)
K. C. HEALD (1937)
F. H. LAHEE (1937)
H. A. LEY (1937)
R. C. MOORE (1937)
F. B. PLUMMER (1937)
JOHN G. BARTRAM (1938)
C. E. DOBBIN (1938)
STANLEY C. HEROLD (1938)
THEODORE A. LINK (1938)
C. V. MILLIKAN (1938)
JOHN L. RICH (1938)
C. W. TOMLINSON (1938)
GLENN H. BOWES (1939)
W. L. GOLDSTON (1939)
W. C. SPOONER (1939)
PARKER D. TRASK (1939)

REPRESENTATIVE ON DIVISION OF GEOLOGY AND GEOGRAPHY NATIONAL RESEARCH COUNCIL

FREDERIC H. LAHEE (1937)

GEOLOGIC NAMES AND CORRELATIONS COMMITTEE

IRA H. CRAM, *chairman*, Pure Oil Company, Tulsa, Oklahoma

JOHN G. BARTRAM
M. G. CHENEY
ALEXANDER DEUSSEN
B. F. HAKE
G. D. HANNA
M. C. ISRAELSKY
A. I. LEVORSEN
C. L. MOODY
R. C. MOORE
ED. W. OWEN
J. R. REEVES
ALLEN C. TESTER
W. A. THOMAS

TRUSTEES OF REVOLVING PUBLICATION FUND

RALPH D. REED (1937)
BEN F. HAKE (1938)
J. V. HOWELL (1939)

TRUSTEES OF RESEARCH FUND

G. C. GESTER (1937)
A. A. BAKER (1938)
ALEX W. MCCOY (1939)

FINANCE COMMITTEE

E. DEGOLYER (1937)
THOMAS S. HARRISON (1938)
W. B. HEROY (1939)

COMMITTEE ON APPLICATIONS OF GEOLOGY

FRANK RINKER CLARK, *chairman*, Box 981, Tulsa, Oklahoma

WILLIAM H. ATKINSON
ARTHUR E. BRAINERD
IRA OTHO BROWN
HAL P. BYBEE
CAREY CRONEIS
H. B. HILL
EARL P. HINDES
MARVIN LEE
S. E. SLIPPER
H. S. MCQUEEN
E. K. SOPER
J. M. VETTER

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 20, NO. 11 (NOVEMBER, 1936), PP. 1523-1528

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

The Panhandle Geological Society, of Amarillo, Texas, sponsored a Wichita Mountains field trip in southwestern Oklahoma, starting from Hobart, Oklahoma, September 25. Examination was made of exposures of "Granite wash," early Paleozoic strata, and pre-Cambrian rocks, the equivalents of which are reached in the subsurface by wells in the Panhandle field. O. A. SEAGER, Carter Oil Company, of Wilson, and FRANK GOUIN, of Duncan, Oklahoma, guided the party. JOHN E. GALLEY, Shell Petroleum Corporation, Amarillo, is president and G. L. KNIGHT, Phillips Petroleum Company, Amarillo, is secretary-treasurer of the society.

HARRY H. POWER, chief production engineer of the Gulf Oil Corporation, Gypsy Division, Tulsa, Oklahoma, joined the faculty of the University of Texas on October 1, in the capacity of chairman of the department of petroleum engineering. Power has been with the Gypsy Oil Company 9 years. He is a member of the American Association of Petroleum Geologists and was recently chairman of the petroleum division of the American Institute of Mining and Metallurgical Engineers.

WILLARD M. PAYNE of The California Company has been transferred to Shreveport, Louisiana, where his address is Box 1395.

W. V. HOWARD has resigned his position at the University of Illinois to take charge of the petroleum division of J. G. Wray and Company, consulting engineers, of Chicago. His offices are at 615 Wright Building, Tulsa, Oklahoma.

PHILIP S. SCHOENECK, of the Atlantic Oil Producing Company, has been transferred from Laredo to San Antonio, Texas. The transfer is being made in connection with the consolidation of the Laredo and San Antonio offices.

C. LATHROP HEROLD is with the Shell Petroleum Corporation, Houston, Texas.

T. WAYLAND VAUGHAN, who recently retired as director of the Scripps Institution of Oceanography, will make his home in Washington, D. C., where he plans to continue his oceanographic work in connection with the United States Geological Survey and the United States National Museum.

J. BROOKES KNIGHT has been appointed curator of Paleozoic invertebrate paleontology in the geological department of Princeton University.

K. D. OWEN and DAVID HEDLEY were the speakers at the meeting of the Houston Geological Society, September 10. They discussed the Placedo field of Victoria County, southern Texas.

L. P. TEAS, formerly Gulf Coast division geologist for the Humble Oil and Refining Company, has been appointed assistant chief geologist and is located in Houston.

MORGAN J. DAVIS has been appointed the Humble Oil and Refining Company's division geologist for the Gulf Coast, replacing TEAS in that position.

C. E. COOK, of the Humble Oil and Refining Company, has been appointed district land man at New Orleans, replacing H. C. VICTERY who has been transferred to Houston.

JOHN B. LUCKE has resigned from the United States Soil Conservation Service to become assistant professor of geology at West Virginia University, Morgantown, West Virginia.

LEO G. KEPPLER has changed his address from San Antonio, Texas, to 1529 South Owasso, Tulsa, Oklahoma.

J. N. GREGORY, consulting geologist, has opened offices in Midland, Texas.

M. B. TUCKER, evaluation engineer, has returned to the production headquarters of the Shell Petroleum Corporation, Tulsa, after two years at the St. Louis general headquarters.

R. B. ROARK, Mid-Continent production manager for the Shell Petroleum Corporation, has been appointed a member of the research advisory group which is conducting research activities on secondary recovery methods at the Pennsylvania State College. These experiments, started in 1933, are conducted under the auspices of the Bradford District Pennsylvania Oil Producers Association with the object of securing a greater ultimate recovery of oil from the Bradford sands.

H. W. THOMS has entirely recovered and is ready for hard work again. He has spent the last several years in the gold country of the Southern Mother Lode, and may be addressed at Box 195, Mariposa, California.

R. G. GREENE has returned from a 2 months' trip into the upper headwaters of the Amazon Basin, eastern Peru, and is now located at 707 Richfield Building, Los Angeles, California.

R. VAN A. MILLS, formerly chief petroleum engineer for the Continental Oil Company, has been made proration engineer.

CHESTER F. BARNES, who for the past 6½ years has been with the geological and geophysical departments of the Humble Oil and Refining Company, has resigned to enter private practice as geologist and geophysicist with central location in Gainesville, Texas (Box 33).

JOSEPH E. POGUE, consulting petroleum engineer and geologist of New York City, has been appointed a vice-president of The Chase National Bank.

ROBERT G. HAMILTON has been transferred from the Houston headquarters of the Schlumberger Well Surveying Corporation to Whorton, Texas, to establish and take charge of a new Schlumberger party.

J. A. ALLAN, professor of geology at the University of Alberta, addressed the young men's section of the Calgary Board of Trade recently on Alberta oil prospects.

J. BEN CARSEY, chief geologist for the Humble Oil and Refining Company in the West Texas division, has been placed in charge of the land and geological activities in West Texas and New Mexico with headquarters in Midland, Texas.

MILWARD MILLER, geologist for the Humble Oil and Refining Company, has been transferred to Hobbs, New Mexico, and WELDON CARTWRIGHT, microscopic geologist, has been transferred to the Midland headquarters of the merged West Texas and New Mexico divisions.

GORDON H. WHITE has changed his address to Shell Petroleum Corporation, 1118 South Texas Bank Building, San Antonio, Texas.

DILWORTH S. HAGER, consulting geologist, was guest speaker at the meeting of the Dallas Petroleum Geologists, September 28, and spoke on the geology of the Talco region.

The Houston Geological Society's officers for the coming year are: PHIL F. MARTYN, president, Houston Oil Company, Petroleum Building; O. L. BRACE, vice-president, consulting geologist, 813 Second National Bank Building; WALLACE C. THOMPSON, secretary-treasurer, General Crude Oil Company, Esperson Building; PERRY OLCOTT, Humble Oil and Refining Company; LON CARTWRIGHT, Skelly Oil Company, and CLIFF BOWLES, Standard Oil Company of Kansas, advisory board officers.

GLENN D. ROBERTSON has returned from The Hague and his headquarters are now with the production department of the Shell Petroleum Corporation, St. Louis.

ROY E. DICKERSON, chief geologist for the Atlantic Refining Company of Cuba, is now located at Room 1411, 260 South Broad Street, Philadelphia, Pennsylvania.

GEORGE E. EKBLAW and RALPH E. GRIM are the authors of "Some Geological Relations between the Constitution of Soil Material and Highway Construction," *Illinois State Geological Survey Report of Investigations No. 42.*

G. W. LEPPER, petroleum geologist, has retired from the Burmah Oil Company after 25 years in the East and has been appointed technical adviser to the petroleum department of the Board of Trade in London. His address is Maplewood, Burdon Lane, Cheam, Surrey.

HENRY EMMETT GROSS, formerly in the exploitation engineering department of the Shell Petroleum Corporation, Tulsa, has been appointed assistant professor of petroleum engineering at the University of Oklahoma, Norman.

FLOYD C. DODSON, geologist, represents the Wilcox Oil and Gas Company at San Angelo, Texas.

EDWARD E. SMITH, JR., has taken a position with the Petty Geophysical Engineering Company at Norman, Oklahoma.

E. W. FOSHAGGE, of the geological department of the Shell Petroleum Corporation, has been transferred from the Tulsa office to Amarillo, Texas.

ROBERT M. DICKEY is the new head of the mineralogy and geology department at the Michigan College of Mining and Technology, Houghton. He replaces C. O. SWANSON who resigned to become professor of mineralogy at the University of British Columbia.

JOHN M. HERALD, consulting geologist, is located at 512 Alexander Building, Tulsa, Oklahoma.

E. G. WOODRUFF, geologist for flood control in the Arkansas Valley District, United States Army Engineers, has his headquarters at Memphis, Tennessee.

The Appalachian Geological Society of Charleston, West Virginia, met at West Virginia University, Morgantown, September 14. Eighty members and guests of the society from West Virginia, Ohio, Pennsylvania, Kentucky, and Michigan, and 15 members of the Oil and Gas Men's Club of Clarksburg were present. A program on "The Oriskany Sandstone of West Virginia" was presented by members of the West Virginia Geological Survey and the department of geology of the University of West Virginia. State geologist PAUL H. PRICE presided and outlined the studies and experiments made during the previous months. Assistant State geologist R. C. TUCKER exhibited an isopach map of the state, showing the thickness of the Devonian shale and the interval between the base of the Berea sandstone and the top of the Corniferous (Onondaga limestone), or the Huntersville chert. J. H. C. MARTENS, head of the geology department of the University, presented a paper on the petrography of the Oriskany in Kanawha County (published in the *Oil and Gas Journal* of October 1). A. J. H. HEADLEE explained the analyses of gas samples from wells in the Charleston Quadrangle. JOHN B. MCCUE, chief chemist of the Survey, described the analyses of brine samples. Preceding the meeting, a banquet was given at the Country Club where C. S. BOUCHER, president of the University, welcomed the guests. On September 15, an excursion trip included a visit to the Chesnut Ridge anticline in Decker's Creek gorge, where the Greenbrier-Pocono contact is exposed, and inspection of the Greer Limestone Company's limestone quarry. J. E. BILLINGSLEY, of the Commonwealth Gas Corporation, is president and ROBERT C. LAFFERTY, of the Owens-Libbey-Owens gas department, is secretary-treasurer of the Appalachian Society.

ROBERT M. WHITESIDE, consulting geologist and operator, may be addressed at Box 2791, Dallas, Texas.

Total membership of the Association on October 1, 1936, was 2,314 (1,887 active or full members); on October 1, 1935, the total was 2,130; and on February 1, 1935, it was 1,909, the low point resulting from general business conditions since 1930. This low of the membership curve lagged behind the low of the general business curve because A.A.P.G. members delinquent in dues were kept on the membership list 2 years before being dropped. The peak of membership was 2,562 on March 1, 1931. If the increase of the past 20 months (400 total) continues, a new peak will be reached in 1938.

The September, 1936, *Bulletin* had a monthly circulation of 2,512 copies (410 non-member subscribers); the September, 1935, circulation was 2,163; in September, 1934, it was, 1,978; in September, 1933, it was 1,870; and in April, 1933, it was 1,511, the low point of the depression. The peak of circula-

tion was 2,827 in March, 1931. The *Bulletin* circulation (both members and non-members) in countries outside the United States was 410 in September, 1936.

The Oklahoma City Geological Society has announced a series of 5 monthly field trips to study the Simpson formation at significant localities. Three of the trips will cover the Simpson section at localities in the Arbuckle Mountains. One trip will be made to outcrops of the formation near the Wichita Mountains and another to outcrops of beds classified as Ordovician in the Ouachita Mountains. CHARLES E. DECKER will be the leader. The first trip was held October 16 and 17. Those who register (fifty cents, registration fee) will be provided with a booklet composed of a detailed graphic section of the Simpson and an areal geologic map. All geologists and their friends are invited. A copy of *Oklahoma Geological Survey Bulletin 55* and one of the Oklahoma City Geological Society road log booklet will be useful. The chairman of the trips committee is J. T. RICHARDS, Gulf Oil Company, Oklahoma City. R. W. LAUGHLIN is president and HENRY SCHWEER is secretary-treasurer of the society.

J. J. ZORICHAK, petroleum engineer with Stanolind Oil and Gas Company, spoke on "Control of Water in Pumping Wells" at the meeting of the American Institute of Mining and Metallurgical Engineers in Fort Worth, October 8.

R. E. SHERRILL, associate professor of geology, University of Pittsburgh, is acting head of the department of oil and gas production during the absence of H. C. GEORGE, who is on leave of absence due to illness. SHERRILL is also a coöperating geologist for the Pennsylvania State Geological Survey.

W. D. KLEINPELL, consulting geologist, spoke on "Newly Discovered Fields in California—1926" at the meeting of the American Institute of Mining and Metallurgical Engineers, Los Angeles, October 1–2.

The advertisement of the Independent Exploration Company on page xix of the October *Bulletin* inadvertently carried the name of the Geophysical Corporation of Colorado in reverse order. The correct advertisement appears on page xix of this issue.

GEORGE R. ELLIOTT is now with Phillips Petroleum Company at Shreveport, Louisiana.

President R. D. REED, of Los Angeles, California, made a trip east in October, appearing on the technical programs of several local societies with an illustrated synopsis of his forthcoming book *Structural Evolution of Southern California*, and conferring with members about Association business. On October 5 he met with the Rocky Mountain Association of Petroleum Geologists at Denver, Colorado. On the 12th he was the guest of honor at a dinner of geologists at Tulsa, Oklahoma, and spoke before the Tulsa Geological Society. On the 17th he addressed the San Antonio Geological Society at the Section's annual program and field trip at Laredo, Texas. On the 20th he met with the Houston Geological Society, and on the 23rd with the West Texas Geological Society and the Midland Geological Society in joint session at Midland, Texas. At the Laredo meeting, the executive committee of the

Association held a meeting. Those present were president REED of Los Angeles, past-president LEVORSEN of Tulsa, vice-president DOBBIN of Denver, and secretary-treasurer ROW of San Antonio.

OTTO STUTZER, of the Saxony School of Mines, and past-president of the Society of Economic Geologists, died at Freiberg, Germany, September 29, 1936.

The Rocky Mountain Association of Petroleum Geologists listened to a paper by J. HARLAN JOHNSON on "Cenozoic Deposits of South Park, Colorado," at Denver, October 19.

New officers of the North Texas Geological Society, Wichita Falls, Texas, were elected on October 9 as follows: president S. G. WAGGONER, consulting geologist, First National Bank Building; vice-president, A. W. WEEKS, Shell Petroleum Corporation; secretary-treasurer, M. L. KERLIN, Shell Petroleum Corporation.

J. E. BRANTLY, president of Drilling and Exploration Company, Inc., announces removal of the company's office from Kettleman Hills to 621 South Hope Street, Los Angeles, California. Other offices are maintained in the Continental Building, Dallas, Texas, and at 25 Broadway, New York City.

J. B. UMPLEBY, geologist and engineer, has moved from Norman, Oklahoma, to 4544 Fifty-fifth Avenue, Northeast, Seattle, Washington.

The executive committee of the Association requests all members planning to attend the 17th International Geological Congress at Moscow, August and September, 1937, or the 2nd World Petroleum Congress at Paris, June, 1937, kindly to notify A.A.P.G. headquarters, Box 1852, Tulsa, Oklahoma.

BASIL B. ZAVOICO has been appointed geologist to the department of petroleum economics of the Chase National Bank of the City of New York. His headquarters will be in Houston.

GEORGE D. BLOOMFIELD is working for the Union Oil Company at its paleontology laboratory at Orcutt, California.

LOUIE C. KIRBY is engaged in geological work for Ultramar SAPA at Lumbreras (FCCNA), Prov. de Salta, Argentina, South America.

H. DE CIZANCOURT, Cie Française des Petroles, has returned to Paris after several months in Afghanistan.

FRANCOIS BIRAUD, age 36, geologist of the Compagnie Française des Petroles, Paris, died by accident in Djeddha, Arabia, on July 13, 1936.

JOHN M. MUIR sailed, in November, for abroad expecting to be absent from America for 12 months. He may be addressed in care of the Association, Box 1852, Tulsa, Oklahoma.

B. COLEMAN RENICK, district geologist of the Magnolia Petroleum Company at San Antonio, has resigned to become associated with the Phillips Drilling Company and is located at 1802 Alamo National Building, San Antonio, Texas.

LEWIS W. MACNAUGHTON has resigned from the Amerada Petroleum Corporation, effective October 31, and is now doing consulting work with headquarters at 611 Continental Building, Dallas, Texas.

PAUL M. BUTTERMORE did the geological and land work in the new producing pool of the Chartiers Oil Company at Mount Pleasant, Michigan.

OKLAHOMA

ELFRED BECK
Geologist
614 National Bank of Tulsa Building
TULSA OKLAHOMA

W. V. HOWARD
Geologist
J. G. WRAY & CO.
Operation—Appraisal
615 Wright Bldg. TULSA
3324 Bankers Bldg. CHICAGO

R. W. Laughlin L. D. Simmons
WELL ELEVATIONS
Oklahoma, Kansas, Texas, and New Mexico
LAUGHLIN-SIMMONS & CO.
605 Oklahoma Gas Building
TULSA OKLAHOMA

G. H. WESTBY
Geologist and Geophysicist
Seismograph Service Corporation
Kennedy Building Tulsa, Oklahoma

GINTER CHEMICAL LABORATORY
Analytical Work on Oil, Gas, Water and Cores
R. L. GINTER
Owner
118 West Cameron
Tulsa

MID-CONTINENT TORSION BALANCE SURVEYS
INTERPRETATIONS
KLAUS EXPLORATION COMPANY
H. KLAUS
Geologist and Geophysicist
404 Broadway Tower Enid, Oklahoma

GEO. C. MATSON
Geologist
Philcade Building TULSA, OKLA.

TEXAS

E. DEGOLYER
Geologist
Esperson Building
Houston, Texas
Continental Building
Dallas, Texas

DAVID DONOGHUE
Consulting Geologist
Appraisals - Evidence - Statistics
Fort Worth National Bank Building
FORT WORTH, TEXAS

D'ARCY M. CASHIN
Geologist *Engineer*
Specialist, Gulf Coast Salt Domes
Examinations, Reports, Appraisals
Estimates of Reserves
705 Nat'l. Standard Bldg.
HOUSTON, TEXAS

ALEXANDER DEUSSEN
Consulting Geologist
Specialist, Gulf Coast Salt Domes
1606 Shell Building
HOUSTON, TEXAS

F. B. Porter
President
R. H. Fash
Vice-President
THE FORT WORTH LABORATORIES
Analyses of Brines, Gas, Minerals, Oil. Interpretation of Water Analyses. Field Gas Testing.
828½ Monroe Street FORT WORTH, TEXAS
Long Distance 138

GEOLOGICAL AND GEOPHYSICAL

COLORADO

ROCKY MOUNTAIN ASSOCIATION OF PETROLEUM GEOLOGISTS
DENVER, COLORADO

President - - - - - - - Ross L. Heaton
2374 Elm Street
Vice-President - - - - W. C. Toepelman
University of Colorado, Boulder
Vice-President - - - - - H. W. Oborne
Box 57, Colorado Springs
Secretary-Treasurer - - - J. Harlan Johnson
Box 336, Colorado School of Mines, Golden, Colo.

Luncheon meetings, first and third Mondays of each month, 6:15 P.M., Auditorium Hotel.

KANSAS

KANSAS GEOLOGICAL SOCIETY
WICHITA, KANSAS

President - - - - - - - R. H. Whortan
705 Fourth National Bank Building
Vice-President - - - - Charles W. Roop
I.T.I.O. Co., 605 Union National Bank Building
Secretary-Treasurer - - - - Harold O. Smedley
Skelly Oil Company, 510 Ellis Singleton Building

Regular Meetings: 7:30 P.M., Allis Hotel, first Tuesday of each month. Visitors cordially welcomed.

The Society sponsors the Kansas Well Log Bureau which is located at 412 Union National Bank Building.

LOUISIANA

THE SHREVEPORT GEOLOGICAL SOCIETY
SHREVEPORT, LOUISIANA

President - - - - - - - Paul E. Nash
Magnolia Petroleum Company
Vice-President - - - - B. W. Blanpied
Gulf Refining Company
Secretary-Treasurer - - - Shapleigh G. Gray
The Texas Company

Meets the first Friday of every month, Civil Courts Room, Caddo Parish Court House. Luncheon every Monday noon, Caddo Hotel.

THE SOCIETY OF PETROLEUM GEOPHYSICISTS

President - - - - - - - L. W. Blau
Humble Oil and Refining Company
Houston, Texas
Vice-President - - - - Gerald H. Westby
Seismograph Service Corporation
Tulsa, Oklahoma
Editor - - - - - - F. M. Kannenstine
Rosaire and Kannenstine
2011 Esperson Building
Houston, Texas
Secretary-Treasurer - - - John H. Wilson
Colorado Geophysical Corporation
610 Midland Savings Building
Denver, Colorado

OKLAHOMA

OKLAHOMA CITY GEOLOGICAL SOCIETY
OKLAHOMA CITY, OKLAHOMA

President - - - - - - - R. W. Laughlin
First National Building
Vice-President - - - - Leland W. Jones
Ohio Oil Company
Secretary-Treasurer - - - - Henry Schweer
2810 First National Building

Meetings: Second Monday, each month, 8:00 P.M., Commerce Exchange Building. Luncheons: Every Monday, 12:15 P.M., Commerce Exchange Building.

SHAWNEE GEOLOGICAL SOCIETY
SHAWNEE, OKLAHOMA

President - - - - - - - Jack M. Copass
Amerada Petroleum Corporation
Vice-President - - - - - Don L. Hyatt
Carter Oil Company
Secretary-Treasurer - - - - M. C. Roberts
The Texas Company

Meets the fourth Monday of each month at 8:00 P.M., at the Aldridge Hotel. Visiting geologists welcome.

THE STRATIGRAPHIC SOCIETY OF TULSA
TULSA, OKLAHOMA

President - - - - - Joseph L. Borden
The Pure Oil Company
Vice-President - - - - Constance Leatherock
The Tide Water Oil Company
Secretary-Treasurer - - R. V. Hollingsworth
Shell Petroleum Corporation, Box 1191

Meetings: Second and fourth Wednesdays, each month, from October to May, inclusive, at 8:00 P.M., third floor, Tulsa Building.

TULSA GEOLOGICAL SOCIETY
TULSA, OKLAHOMA

President - - - - - - - R. B. Rutledge
Skelly Oil Company
1st Vice-President - - - - G. S. Lambert
Shell Petroleum Corporation
2nd Vice-President - - Lucian H. Walker
614 Atlas Life Building
Secretary-Treasurer - - - Larry D. Simmons
Oklahoma Natural Gas Building
Editor - - - - - - - - John S. Redfield
Stanolind Oil and Gas Company

Meetings: First and third Mondays, each month, from October to May, inclusive, at 8:00 P.M., fourth floor, Tulsa Building. Luncheons: Every Thursday, fourth floor, Tulsa Building.

PRICE LIST

PUBLICATIONS

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

Box 1852, Tulsa, Oklahoma

The *Bulletin* of The American Association of Petroleum Geologists, the official monthly publication of the largest organized body of geologists in the world, occupies a pre-eminent position as an authority in the field of petroleum geology. It contains illustrated articles, notes, discussions, and reviews. Annual subscription, $15.00 (outside United States, $15.40). The contents of Vols. I–X (1917–1926) may be found in the 10-volume Index which sells for $1.00, or in the new comprehensive Index of all A.A.P.G. publications (1917–1936) which will contain approximately 400 pages and will be ready after March, 1937.

This price list indicates the contents of each number of Vols. XI–XX (1927–1936) by states and countries in alphabetical order, and should be useful as an abbreviated subject index. Each December *Bulletin* contains the year's title pages, table of contents, and index. The Association also publishes books on special subjects of petroleum geology. All prices quoted are postpaid. Special prices on request to members, associates, subscribers, and educational institutions.

* An asterisk (*) indicates supply exhausted.

† A dagger (†) indicates available only with purchase of complete set in so far as available.

() Prices in parentheses, special to paid-up members and associates.

BULLETINS (1917–1926)

*1917 **VOL. I.**—159 pp.
1918 **VOL. II.**—176 pp. 6 x 9 in. Paper $4.00
1919 **VOL. III.**—445 pp. 6 x 9 in. Paper 5.00
1920 **VOL. IV.**—338 pp. 6.125 x 9.25 in. 3 Nos. Paper. Each 3.00
***NOS. 1–2. †NO. 3**
1921 **VOL. V.**—724 pp. 6.75 x 10.25 in. 6 Nos. Paper. Each (except **NO. 2,** $3.50) 2.00
WHOLE VOLUME WITH INDEX. Cloth 12.00
†NO. 1. NOS. 2–6
1922 **VOL. VI.**—600 pp. 6.75 x 10.5 in. 6 Nos. Paper. Each 2.00
***NOS. 1. NOS. 2–6**
1923 **VOL. VII.**—730 pp., with index to Vols. I–VI. 6.75 x 9.5 in. 6 Nos. Paper. Each 2.00
1924 **VOL. VIII.**—860 pp. 6.75 x 9.5 in. 6 Nos. Paper. Each 2.00
NO. 1. *NO. 2. NOS. 3–6
1925 **VOL. IX.**—1,319 pp. 6.75 x 9.5 in. 9 Nos. Paper. Each (except **NOS. 1–3,** $3.00) ($1.00) 1.50
1926 **VOL. X.**—1,339 pp. 6.75 x 9.5 in. 12 Nos. Paper. Each (except **NOS. 3, 11, 12,** $2.00) .... ($1.00) 1.50
†WHOLE VOLUME WITH INDEX. Bound in 2 parts. Cloth 17.00

BULLETINS (1927–1936)

1927 **VOL. XI.**—1,376 pp. 12 Nos. Paper. Each .... ($1.00) 1.50
WHOLE VOLUME WITH INDEX. Bound in two parts. Cloth .... ($5.00) 17.00

***NO. 1.**—110 pp. (Available in bound volume.)
ARKANSAS: Upper Cretaceous. AUSTRALIA: Prospects. CALIFORNIA: Miocene, Ventura district. GENERAL: Cordilleran geosyncline, accumulation; folding or shearing. KANSAS: Ordovician deep wells. NEW MEXICO: Schist east of Santa Rosa. TEXAS: Upper Cretaceous. WASHINGTON: Oil in basalt.

†NO. 2.—111 pp. COLOMBIA: Prospects. COLORADO-UTAH: Salt domes. GENERAL: Hardness, rocks. JAPAN: Gas. NEW GUINEA: Search for oil. OKLAHOMA: Folding. PALESTINE: Prospects. VENEZUELA: Maracaibo Basin.

***NO. 3.**—134 pp. ARKANSAS: Ozarks. ARGENTINA: Mendoza. CANADA: Alberta. GENERAL: Alkaline flooding; distribution geologists. VENEZUELA: Medicine.

†NO. 4.—83 pp. CALIFORNIA: Heavy minerals, San Joaquin Valley; Coastal physiog-

raphy; Petaluma, Sonoma Co. GENERAL: Heavy minerals; plane table underground. OREGON: Asphalts. SIAM: Geology and petroleum. UTAH: Salt domes.

†**NO. 5.**—112 pp. ARKANSAS: Lower Cretaceous. GENERAL: Carbon ratio theory. KENTUCKY: Eastern fields. OKLAHOMA: Lower Cretaceous. RUSSIA: Development. TEXAS: Westbrook, Mitchell Co.

NO. 6—99 pp. BURMA: Fields. CALIFORNIA: San Joaquin Valley; McKittrick. GENERAL: Compaction and structure. INDIANA: Tri-County field. TEXAS: Yates pool, Pecos Co.; Ranger sand, Eastland Co. WEST VIRGINIA: Copley pool.

†**NO. 7**—127 pp. GENERAL: Convergence, Mid-Continent; criteria; oil occurrence; stratigraphic distribution petroleum; alignment chart; geologic sections. OKLAHOMA: Cimarron Co. TEXAS: Big lime; Goose Creek subsidence. VIRGINIA: Lee Co. seep. WEST VIRGINIA: Cabin Creek. WYOMING: Chugwater-Sundance.

NO. 8—119 pp. CALIFORNIA: Seal Beach and Alamitos. GENERAL: Epi-anticlinal faults; gravitational compaction; samplograph; dip and strike symbols. KANSAS: Pre-Cambrian petrography. OKLAHOMA: Garvin Co. TEXAS: San Marcos Quadrangle; subsidence Goose Creek field. UTAH: Structure stratigraphy.

NO. 9—116 pp. GENERAL: Carbon-ratio. ILLINOIS: Wabash Co. INDIANA: Southwestern developments. KANSAS: Nemaha Mountains. MICHIGAN: Saginaw field. OHIO: Structure. OKLAHOMA: Turkey Mountain lime pool; Ordovician correlations. TENNESSEE: Structure and accumulation. VENEZUELA: Marine Eocene.

NO. 10—115 pp. GENERAL: Well-log correction. NEVADA: Oil seep. OHIO: Structure producing sands. OKLAHOMA: Burbank field, Osage Co.; Crinerville field, Carter Co.; Morrison field, Pawnee Co.; Glenn Pool, Creek Co.; Seminole uplift. RUSSIA: New Grosny water problems. TEXAS: Western development.

NO. 11—114 pp. GENERAL: Organic sediments; geologic distillation; pipe capacity; epi-anticlinal faults. KANSAS: Greenwood Co. structure. MEXICO: Hidalgo and Vera Cruz. WYOMING: Chugwater-Sundance contact.

†**NO. 12**—124 pp. ECUADOR: East Andean exploration. GENERAL: Connate and diagenetic waters. OKLAHOMA: Mississippian. WASHINGTON: Olympic peninsula.

1928 VOL. XII.—1,204 pp. 12 Nos. Paper. Each .... ($1.00) 1.50

WHOLE VOLUME WITH INDEX. Bound in two parts. Cloth .... ($5.00) 17.00

†**NO. 1**—110 pp. CALIFORNIA: Red sandstone color. CANADA: Diamond drilling, Turner Valley. GENERAL: Rotary cuttings; technical papers; fused sands. PERU: Northwest. TEXAS: Eastern stratigraphy; South Bend production, Young Co.

†**NO. 2**—98 pp. CALIFORNIA: Southern Pleistocene. GENERAL: Paleozoic volcanics. IOWA: Field conference. KANSAS: Stratigraphy Salina Basin. MISSOURI: Field conference. TEXAS: Panhandle gas.

†**NO. 3**—119 pp. CALIFORNIA: Pico formation, Ventura quadrangle; heavy minerals, sandstone dyke, Orange Co. GENERAL: Cement accelerators.

†**NO. 4**—108 pp. GENERAL: Rock pressure. LOUISIANA: Vinton salt dome, Calcasieu Parish. MEXICO: Panuco field.

†**NO. 5**—134 pp. CALIFORNIA: Consequent streams. GENERAL: Production; synclinal oil; diatoms; origin. GERMANY: Fields. OKLAHOMA: Osage Co. TEXAS: Salt domes.

†**NO. 6**—94 pp. CALIFORNIA: southern development. ECUADOR: Miocene. GENERAL: Shore-line deposits, Jamin action. OKLAHOMA: Osage Co.

NO. 7—101 pp. ARGENTINA: Mendoza. ARKANSAS: Rainbow City. CALIFORNIA: Ventura Avenue; Sespe formation; Adams Canyon foraminifera. GENERAL: Horizontal Faulting. KANSAS: Rose dome. OKLAHOMA: Weatherford; well temperatures.

NO. 8—93 pp. GENERAL: Carbon-ratio; thrusting; magnetic variometer; jointing.

NO. 9—100 pp. GENERAL: Gravity; rock color; research and A.A.P.G.

NO. 10—79 pp. ARKANSAS: Trinity sandstone and Jurassic peneplain. CALIFORNIA: Monterey shale. KANSAS: Volcanic ash. LOUISIANA: Basalt, Richland Parish gas field. OKLAHOMA: Trinity sandstone, Jurassic peneplain. TEXAS: Distillation of oil from organic sediments, asphalt in Anacacho.

NO. 11—87 pp. ARKANSAS: Trinity. FLORIDA: Basement. GENERAL: Source, compaction, migration; gas reserves. OKLAHOMA: Trinity. TEXAS: Trinity.

NO. 12—67 pp. GENERAL: Examining cuttings; limestone reservoirs; isostasy. TEXAS: Clay Creek dome, Washington Co. WYOMING: Big Sand Draw field.

1929 VOL. XIII.—1,610 pp. 12 Nos. Paper. Each .... ($1.00) 1.50

WHOLE VOLUME WITH INDEX. Bound in two parts. Cloth .... ($5.00) 17.00

NO. 1—100 pp. GENERAL: Differential compaction; torsion balance—topographic corrections; geologic distillation. OKLAHOMA: Uplifts; en échelon faults.

NO. 2—98 pp. CALIFORNIA: San Joaquin Valley. COLORADO: Sangre de Cristo conglomerates. GENERAL: Course of holes; A.A.P.G. history; hauerite on salt-domes. NEW MEXICO: Shiprock. TEXAS: Correlation, Permian basin.

NO. 3—104 pp. CALIFORNIA: Valle Grande tectonics.

NO. 4—106 pp. ECUADOR: Guayaquil limestone. GENERAL: Oil by shearing. KANSAS: Shale gas. TEXAS: Galena, sphalerite, Orchard salt dome, Fort Bend Co.
NO. 5—148 pp. CALIFORNIA: Sespe, Modelo formations. GENERAL: Tectonic classification oil fields; Pennsylvanian life. KANSAS: Pre-Mississippian.
NO. 6—156 pp. ARKANSAS: Brownstown formation. GENERAL: Mid-Continent Carboniferous; en échelon faults; Hotchkiss superdip; rock volume. KANSAS: Smoky Hill chalk; subsidence. NEW MEXICO: Capitan limestone. TEXAS: 1928 development; Capitan limestone. VENEZUELA: Cretaceous-Eocene unconformity.
NO. 7—170 pp. ALASKA: Mother rocks, microthermal studies; fossil plants. COLORADO: Benton paleogeography. GENERAL: By-passing, discontinuous deposition; terrane effects; crooked holes. MONTANA: Sweetgrass arch. RUSSIA: Oil, water content of sands, Grozny; Oural-Volga Permian basin. TEXAS: Helium, Amarillo fold.
NO. 8—212 pp. NEW MEXICO: Pennsylvanian-Permian. OKLAHOMA: Pennsylvanian. TEXAS: Pennsylvanian-Permian; Triassic; Cretaceous on salt domes; Concho Bluffs, Crane, Ector, and Winkler Cos.
NO. 9—152 pp. BRAZIL: São Paulo. GENERAL: Crooked holes; magnetometer, torsion-balance surveys; strike-and-dip solution. KANSAS: Mohawkian sediments. TEXAS: Fisk pool, Coleman Co. VENEZUELA: developments.
NO. 10—165 pp. FRANCE: Pechelbronn temperature. GENERAL: Rocky Mountain carbon ratios, unsymmetrical anticlines; undergraduate training. INDIANA: West Franklin formation. JAPAN: Bituminous shale. LOUISIANA: Claiborne. OKLAHOMA: Oklahoma City. TEXAS: Georgetown; Upper Cretaceous unconformities; Claiborne; Mt. Sylvan salt dome, Smith Co.; Darst Creek fault, Guadalupe Co.
NO. 11—96 pp. ARIZONA: Permian. CALIFORNIA: Kettleman Hills. COLORADO: Permian. GENERAL: Strain ellipsoid; organic acids and limestone. NEW MEXICO: Permian. OKLAHOMA: Arbuckle limestone. UTAH: Permian.
NO. 12—104 pp. GENERAL: Structural contouring; alidade long shots. TEXAS: Yates pool, Pecos Co.; Van field, Van Zandt Co.

1930 VOL. XIV.—1,610 pp. 12 Nos. Paper. Each .... ($1.00) 1.50
WHOLE VOLUME WITH INDEX. Bound in two parts. Cloth..................($5.00) 17.50
NO. 1—119 pp. GENERAL: Density, porosity, compaction, migration; submarine data. MEXICO: Sierra Madre Oriental and south fields. OKLAHOMA: Southwestern; Ouachita orogeny. RUSSIA: Geophysical prospecting.
NO. 2—142 pp. ARKANSAS: Hale Mountain. GENERAL: Sulphate-reducing bacteria; seismic interpretation; geophysical prospecting; Bulimina jacksonensis zone. LOUISIANA: Magnetometer on Caddo-Shreveport uplift. OKLAHOMA: Permian in northwest; Simpson vs. "Detrital."
NO. 3—137 pp. CALIFORNIA: Fractures, Santa Barbara Co. ECUADOR: Southwest. GENERAL: Source sediments; International Geological Congress; World Engineering Congress. KANSAS: Cave-ins, Wallace Co. TEXAS: Basement rocks, Pecos Co.; Taylor chalk, Jacksonville embayment.
NO. 4—132 pp. CALIFORNIA: McLure shale, Coalinga. GENERAL: Sandstone dikes and migration; shearing pressures, oil shales; experimental salt domes; lignite in dolomite. INDIANA: Tri-county field. LOUISIANA: Catahoula Parish. TEXAS: Magnetometer in Little Fry Pan, Uvalde and Kinney Cos.
NO. 5—151 pp. GENERAL: History petroleum geology; orientation, cores, bore holes; Gulf Coast crooked holes; bacteria discolor sediments; oil-field structure. OKLAHOMA: Geothermal gradients; Paleozoic, Wichita Mountains. SOUTH DAKOTA: Minnelusa, Black Hills. TEXAS: Ordovician, Big Lake, Reagan Co.
NO. 6—142 pp. COLORADO: Unconformity, Colorado group. GENERAL: Ancestral Rockies; type locality of faults; original recommendations. ILLINOIS: State survey. LOUISIANA: Dixie pool, Caddo Parish. TEXAS: Yates pool, Pecos Co.; Barbers Hills, Chambers Co.; Big Lake, Reagan Co. TURKEY: Prospects.
NO. 7—140 pp. ARKANSAS: Faulting, southwest. AUSTRALIA: Oil well. GENERAL: Fault type locality. ILLINOIS: Cretaceous, Tertiary. KENTUCKY: Cretaceous, Tertiary. LOUISIANA: Mississippi delta; Gulf Coastal prairies. MISSOURI: Cretaceous, Tertiary. TEXAS: Larremore area, Caldwell Co.; Hendrick pool, Winkler Co.
NO. 8—135 pp. CALIFORNIA: Geothermal variations. COLORADO: Vermilion Creek gas; bentonite, Rosencranz area. GENERAL: Salt-dome problem; airplane mappings; deflecting diamond-drill holes; stratigraphic names. KANSAS: Bentonite, Rosencranz. LOUISIANA: Cotton Valley, Webster Parish; Sulphur dome, Calcasieu Parish. NEW MEXICO: Permian basin. WYOMING: Vermilion Creek.
NO. 9—144 pp. GENERAL: Iso-cons, Ordovician waters; geophysical prospecting, TEXAS: Esperson dome, Liberty Co.; Salt Flat, Caldwell Co.; Yoast, Bastrop Co.
NO. 10—129 pp. CALIFORNIA: Kreyenhagen shale, Fresno Co. GENERAL: Marmaton and Cherokee; Pennsylvanian climates; physical analysis, oil sands. KANSAS: Richmond fossils, Viola. TEXAS: Surface, southeast; Saxet oil, Nueces Co.
NO. 11—113 pp. CALIFORNIA: "Lower Pliocene," Puente Hills, San Bernardino Co. GENERAL: Origin, LOUISIANA: Gulf Coast potentialities; secondary salt-dome ma-

terials. SUMATRA: Test-pits. TEXAS: Gulf Coast potentialities; Salt Flat, Caldwell Co.; Rio Grande embayment; secondary salt-dome materials; Glen Rose gas.
NO. 12—118 pp. CALIFORNIA: Elastic-wave surveys. KANSAS: Pre-Mississippian. OKLAHOMA: Simpson group; Oklahoma City; pre-Mississippian.

1931 VOL. XV.—1,476 pp. 12 Nos. Paper. Each .... ($1.00) 1.50
WHOLE VOLUME WITH INDEX. Bound in two parts. Cloth .... ($5.00) 17.00

NO. 1—111 pp. GENERAL: Vegetation, geologic indicator; salt domes and accumulation; petroleum generation; strike and dip solution. POLAND: Oil fields, Carpathian Mountains. TEXAS: Clay Creek, Washington Co.
NO. 2—116 pp. CALIFORNIA: Tulare horizon, Kings Co. GENERAL: Edge-water capillarity; metamorphism, source rocks; mechanics. KANSAS: Subsidence, Hamilton Co. NEW YORK: Black shales. OKLAHOMA: Bristow. TEXAS: Midway fauna; oil, White Point gas, San Patricio Co. WYOMING: Minnelusa, Black Hills.
NO. 3—138 pp. CALIFORNIA: Collophane, brown shales. GENERAL: Compaction. LOUISIANA: East Hackberry salt dome, Cameron Parish; Chestnut dome, Natchitoches Parish. VENEZUELA: Cretaceous limestone source rock.
NO. 4—123 pp. GENERAL: Correlation; orogenies; bacterial genesis; underground storage. OKLAHOMA: Permian. TEXAS: Hockley salt dome, Harris Co.; Yeager clay, Webb and Live Oak Cos. WYOMING: Geophysics, Yellowstone Park.
NO. 5—106 pp. CALIFORNIA: Cenozoic. CANADA: Alberta syncline. GENERAL: Cap rock. LOUISIANA: Sabine uplift. MONTANA-WYOMING: Deeper drilling.
NO. 6—134 pp. CALIFORNIA: Maricopa Flat, Kern Co.; Fruitvale; Cretaceous-Eocene Coalinga. CANADA: Anticlinal theory. GENERAL: Chemical origin; nomenclature. NEW YORK: Gas. PENNSYLVANIA: Gas. TURKEY: Possibilities.
NO. 7—135 pp. CALIFORNIA: Geothermal variations, Coalinga, producing horizon, Kettleman Hills. GENERAL: Microscopic subsurface work; pre-Cretaceous, Gulf Coastal Plain. KANSAS: Clastic dike, Fort Hays chalk. NEW YORK: Oriskany gas. PENNSYLVANIA: Oriskany gas. TEXAS: Mirando and Pettus districts; San Miguel formation, Maverick Co.; pre-Cretaceous, Balcones fault; East Texas.
NO. 8—124 pp. ARKANSAS: Cretaceous chalks. GENERAL: Migration. LOUISIANA: Richland gas field. MEXICO: Northeastern. PENNSYLVANIA: Deep sand, Tioga. TEXAS: Refugio; Cretaceous chalks. VENEZUELA: Waters.
NO. 9—132 pp. GENERAL: Permo-Carboniferous orogeny, south-central U. S.; silicification and unconformities. NEW MEXICO: Southeastern. TEXAS: Yates, Pecos Co.; Marathon uplift. UTAH: Marine Jurassic (Sundance).
NO. 10—184 pp. ALBERTA: Stratigraphy, southern plains; Red Coulee; Lethbridge-Brooks; Milk River Ridge; Keho Lake-Bassano; Spring Coulee. LOUISIANA: Zwolle field. MONTANA: Jurassic (Ellis), Sweetgrass Hills.
NO. 11—102 pp. Symposium. Geophysics. CALIFORNIA: Magnetometer surveys. GENERAL: Seismography and geological problems; magnetic disturbance and buried casing; Brunton compass attachment for horizontal magnetic intensity. LOUISIANA: Belle Isle, St. Mary Parish, torsion-balance survey.
NO. 12—68 pp. Symposium: Geophysics. CALIFORNIA: Torsion-balance results. GENERAL: Seismograph work with existing wells. KANSAS: Granite ridge pools, source of oil. OKLAHOMA: Granite ridge pools.

1932 VOL. XVI.—1,378 pp. 12 Nos. Paper. Each .... ($1.00) 1.50
WHOLE VOLUME WITH INDEX. Bound in two parts. Cloth .... ($5.00) 17.00

NO. 1—118 pp. GENERAL: Great Basin; true dip; latitude and longitude; Permo-Carboniferous, south-central U. S. MICHIGAN: Fluorite, Mt. Pleasant. NEW MEXICO: Hobbs, Lea Co. TEXAS: Silurian and Devonian, Van Horn; Frio clay.
NO. 2—111 pp. CALIFORNIA: Lower Pliocene, Santa Maria district; Sespe-Piru Creek district. GERMANY: Salt bodies. MICHIGAN: Structural basin; Muskegon field. MISSISSIPPI: Earth cracks. OKLAHOMA: Lower Permian, Cleveland, McClain, Garvin Cos. TEXAS: Bryson field, Jack Co.; South Permian basin; Bonham clay; Luling field, Caldwell Co.; Pecan Gap chalk, Red River and Bowie Cos.
NO. 3—104 pp. COLORADO: Greasewood Flats. GENERAL: Carrier beds. KENTUCKY: Fields. LOUISIANA: Cameron Meadows, Iowa. TEXAS: Frio.
NO. 4—108 pp. CALIFORNIA: Possibilities, Central Valley; producing horizon, Kettleman Hills. GENERAL: Ground water and geologic structure; permeability. TEXAS: Oil in Pleistocene, Corpus Christi; waters, temperatures, north-central.
NO. 5—90 pp. AFRICA: Northern exploration. ALABAMA: Lower Peachtree area. GENERAL: Bioherm and biostrome. KANSAS: Central uplift; Hunton. MISSISSIPPI: Meridian area, Lauderdale Co. TEXAS: Overhanging cap, Barbers Hill, Chambers Co.; Bend age, Sierra Diablo, Culberson Co.; grain interpretation.
NO. 6—96 pp. ARKANSAS: Salt, Smackover, Union Co. ARGENTINA: Faults, Comodoro Rivadavia. CALIFORNIA: Producing horizon, Kettleman Hills. LOUISIANA: Catahoula-Fleming, Vernon Parish; Vicksburg, test, Acadia Parish. TEXAS: Permian salt-type structure; Boggy Creek salt dome, Anderson and Cherokee Cos.

NO. 7—88 pp. COLORADO: Fox Hills formation. GENERAL: Buried hills, central Ozarks; rotary well cuttings. NEW YORK: Finger Lakes region. TEXAS: Structure, Cretaceous, Edwards plateau; High Island dome, Galveston Co.

NO. 8—143 pp. Symposium: Petroleum in Igneous Rocks. ARGENTINA: Volcanic plugs, Mendoza. CALIFORNIA: Metamorphics, San Gabriel Mts., Los Angeles Co. CANADA: Belt series; bitumen, Queen Charlotte Islands, British Columbia. COLORADO: Crystallines. CUBA: Igneous rocks. FRANCE: Limagne. MEXICO: Igneous rocks. MICHIGAN: Bitumen, Nonesuch formation, Keweenawan series. NEW YORK: Pre-Cambrian at Edwards. NEW ZEALAND: Taranski field. TEXAS: Igneous rocks, Coastal Plain. VIRGINIA: Graphite in quartzites.

NO. 9—96 pp. Symposium: Reservoir conditions. CUBA: Aptychus formations. GENERAL: Bottom-hole pressures; density-porosity; subterranean water. MONTANA: Producing formations. OKLAHOMA: Encroachment, Bartlesville sand pools. TEXAS: Bottom-hole pressures, recovery, East Texas. WYOMING: Producing formations.

NO. 10—104 pp. GENERAL: Oil genesis by high radial axial pressure; oil density; time equivalent, lithologic extensions. OKLAHOMA: Oklahoma City field.

NO. 11—110 pp. FRANCE: Possibilities. GERMANY: Occurrence and production. ITALY: Parma district. POLAND: Geology and mining, petroleum.

NO. 12—208 pp. Symposium: Geophysics. GENERAL: Magnetic vectors, structure, oil states; reflection; depth calculation, refraction; seismic weathered layer; relative gravity; equipotential surface curvature; resistivity radon and heavy minerals. LOUISIANA: Vermilion Bay salt dome. OKLAHOMA: Oklahoma City magnetic survey.

1933 **VOL. XVII.**—1,567 pp. 12 Nos. Paper. Each .... ($1.00) 1.50

†WHOLE VOLUME WITH INDEX. Bound in two parts. Cloth .... ($4.00) 17.00

NO. 1—108 pp. CALIFORNIA: McKittrick field, Kern Co.; Eocene, Salinas Valley; "Lillis formation." GENERAL: Microflora of oil waters; base replacement, shales; coral reefs; geophysics; Permo-Carboniferous. KANSAS: Graptolites. MISSISSIPPI: Pre-Tertiary, deep wells at Jackson. TEXAS: Darst Creek field, Guadalupe Co.

NO. 2—102 pp. ALABAMA: Ackerman formation. GENERAL: Ancestral Rockies, Mesozoic and late Paleozoic. KANSAS: Voshell pool, McPherson Co.

NO. 3—140 pp. CALIFORNIA: Seismograph. COLOMBIA: Andes. MONTANA: Producing formations. OKLAHOMA: Permian, Logan and Lincoln Cos. PERSIA: Reservoir. VENEZUELA: Andes. WYOMING: Producing formations.

*NO. 4—102 pp. CALIFORNIA: Gas, Marysville Buttes. COLORADO: Unconformities; pre-Pennsylvanian, Front Range, Montana group; Cretaceous; Greasewood area, Weld and Morgan Cos. GENERAL: Submarine exploration. TEXAS: Galena, Pierce Junction dome, Harris Co.; Balcones fault, McLennan Co.

*NO. 5—160 pp. LOUISIANA: Gulf Coast developments. OKLAHOMA: Permian, Logan and Lincoln Cos. PERSIA: Reservoir rocks. TEXAS: Coastal Plain.

*NO. 6—144 pp. CALIFORNIA: Fault, Buena Vista Hills field, Kern Co.; Long Beach earthquake. GENERAL: Cap rock, oil accumulation; dip angle projection; origin. LOUISIANA: Tertiary. MONTANA: Beartooth-Bighorn region. TEXAS: Kelsey anticline, Upshur Co.; Kincaid Midway. WYOMING: Beartooth-Bighorn.

*NO. 7—120 pp. COLORADO: Permian algal reef, South Park. GENERAL: Preservation of oil during erosion; rock-unit classification. KANSAS: Oil-pool distribution and pre-Mississippian structure. LOUISIANA: Tertiary. OKLAHOMA: Overturned beds, Arbuckle Mountains. TEXAS: East Texas field; Driscoll pool, Duval Co.

*NO. 8—148 pp. CALIFORNIA: Monterey. COLORADO: Paradox. GENERAL: Oil-Field development. MISSOURI: Cretaceous, Crowleys Ridge. TEXAS: Gas, Amarillo; diatrophism and topography, Corpus Christi. UTAH: Paradox.

*NO. 9—136 pp. CALIFORNIA: Encroachment, Casmalia. GENERAL: Pseudotectonic structures; paleogeology, accumulation; geological congress. LOUISIANA: salt domes. POLAND: fields. RUSSIA: Apsheron Peninsula. TEXAS: Salt domes.

*NO. 10—132 pp. CALIFORNIA: Kettleman Hills. GENERAL: Chloride brines; oil, heat and oil shales; fatty, waxy substances and hydrocarbons; oil during erosion. KANSAS: Intrusives, Silver City. TEXAS: Surface fractures; Reynosa, caliche.

*NO. 11—112 pp. ALABAMA: Cocoa sand, Jackson formation. ECUADOR: Beekite in Tertiary. GENERAL: Exogyra cancellata zone. TEXAS: Jackson group; Frio, Vicksburg formations; Sugarland field, Fort Bend Co.; Permian sea island.

*NO. 12—163 pp. GENERAL: Gulf Coast geosyncline; Jamin effect; Coastal Plain. KANSAS: Zinc-lead field. LOUISIANA: Overhanging domes. MISSOURI: Blue Springs gas field, Jackson Co. OKLAHOMA: Viola limestone, Zinc-lead field. PENNSYLVANIA: Clay dikes, Redstone coal. TEXAS: Raccoon Bend, Austin Co.; overhanging salt; Reynosa, caliche. WEST VIRGINIA: Clay dikes, Redstone coal.

1934 **VOL. XVII.**—1,737 pp. 12 Nos. Paper. Each .... ($1.00) 1.50

WHOLE VOLUME WITH INDEX. Bound in two parts. Cloth .... ($4.00) 17.00

†NO. 1—160 pp. Symposium: Geophysics. BAVARIA: Magnetic and torsion-balance survey, Munich basin. GENERAL: Geophysics and geology; geothermics; resistivities;

radio-activity of soil gases; dip shooting; barometric surveying; thickness calculation. KENTUCKY: Magnetic vectors. MICHIGAN: Magnetic vectors. OKLAHOMA: Velocity, Arbuckle Mountains.

†**NO.** 2—122 pp. AUSTRALIA: Gas. GENERAL: Permeability. KANSAS: Hunton limestone, McPherson and Harvey Cos. LOUISIANA: Cap-rock minerals. NEW GUINEA: Gas. OKLAHOMA: Faults; Oklahoma City. PENNSYLVANIA: Bradford sand. TEXAS: Salt-dome minerals; gas, Anderson and Leon Cos.; Woodbine core.

†**NO.** 3—152 pp. BURMA: Gas. CALIFORNIA: Huntington Beach. GENERAL: Estimating reserves; base exchange and clay; cartographic terminology. INDIA: Gas. MONTANA: Paleozoic and Mesozoic, Cinnabar Mtn., Park Co. WYOMING: Paleozoic and Mesozoic, Yellowstone Park.

NO. 4—132 pp. CALIFORNIA: Kettleman Hills; San Joaquin clay. COLORADO: Mississippian. GENERAL: Jamin effect. LOUISIANA: Gulf Coast; Valentine (La Rose) dome by seismograph. TEXAS: Gulf Coast; McFaddin-O'Connor, Greta, Fox, Refugio, White Point, Saxet fields; siderite, Carlos dome, Grimes Co.

NO. 5—152 pp. OKLAHOMA: Arbuckle Mountains. RUSSIA: SE. Caucasus.

†**NO.** 6—128 pp. CALIFORNIA: Pliocene, Los Angeles basin. GENERAL: European oil and gas; Ponto-Caspian, Mediterranean oil deposits and paleogeography; air-blowers; thickness, depth calculations. GERMANY: Gas. RUSSIA: Gas.

†**NO.** 7—124 pp. COLORADO: Two Buttes dome; Hermosa formation. GENERAL: Two decades of oil finding. HUNGARY: Tectonics, paleogeography. JAPAN: Resources. POLAND: Gas. ROUMANIA: Gas. TEXAS: Lissie, Beaumont formations. WASHINGTON: Rattlesnake Hills gas field, Benton Co.

NO. 8—132 pp. ARKANSAS: Ouachita Mountains; Paleozoics and Mid-Continent fields. GENERAL: Reserves; cap rock and accumulation. OKLAHOMA: Ouachita Mountains; Paleozoics and Mid-Continent fields; Hoxbar formation.

NO. 9—124 pp. AFRICA: Belgian Congo oil. ARKANSAS: Osage (Mississippian). BELGIUM: Oil. GENERAL: Organic content; fluid mechanics of salt domes; origin of oil. KENTUCKY: Origin of oil. MISSOURI: Osage. OKLAHOMA: Osage.

NO. 10—160 pp. CALIFORNIA: Mesozoic. GENERAL: Origin, age, Gulf salt. KANSAS: Bartlesville shoestring sands. OKLAHOMA: Blaine anhydrite-gypsum.

NO. 11—172 pp. CANADA: Alberta shale; Turner Valley. COLORADO: Fossil sink holes, Cretaceous, Prowers Co.; Two Buttes dome. GENERAL: Unit operation; coalification. TEXAS: Pecan Gap chalk; Trans-Pecos Upper Mississippian.

NO. 12—179 pp. CALIFORNIA: Heavy minerals, Kettleman Hills. GENERAL: Portable laboratory. KANSAS: Bartlesville shoestring sands. KENTUCKY: Cumberland thrust. NEBRASKA: Pre-Pennsylvanian. TENNESSEE: Cumberland thrust. TEXAS: Esperson dome, Liberty Co.; Permian, Concho Co.; Fredericksburg-Washita contact, Edwards Plateau. VIRGINIA: Cumberland thrust. WYOMING: Chugwater.

1935 **VOL. XIX.**—1,864 pp. 12 Nos. Paper. Each .... ($1.00) 1.50

WHOLE VOLUME WITH INDEX. Bound in two parts. Cloth .... ($4.00) 17.00

NO. 1—152 pp. Symposium: Geophysics. CUBA: Jurassic. GENERAL: Seismic velocities; moisture and elastic waves; gravity Gulf Coast; anisotropy and resistivity; electrical prospecting; geothermal gradient. JAPAN: Torsion balance in Suwa Basin. TEXAS: Torsion balance and overhang, Barbers Hill, Chambers Co.

NO. 2—164 pp. CALIFORNIA: Marine oil shale, Playa del Rey. CANADA: Athabaska oil sands; Alberta shales. GENERAL: Soft-rock deformation; Bituminous shales. NEW MEXICO: Upper Permian, Delaware basin. TEXAS: Producing rock. Hilbig, Bastrop Co.; Trans-Pecos structure; Upper Permian, Delaware basin.

†**NO.** 3—152 pp. GENERAL: Geophysics and salt domes; Pennsylvanian limestone residues; stratigraphical, structural studies, mining regions. OKLAHOMA: Tatums pool, Carter Co. TEXAS: Corpus Christi structural basin and salinity; Buckeye field, Matagorda Co.

NO. 4—120 pp. CALIFORNIA: Vaqueros formation. GENERAL: Petroleum development in America; geothermal gradient. OKLAHOMA: Pennsylvanian surface, oil and gas sands, Muskogee Co. TEXAS: Greta field, Refugio Co. WYOMING: Anticlines between Hiawatha gas field and Baggs.

NO. 5—180 pp. ARKANSAS: Midway. CANADA: Alberta shales. GENERAL: Metamophism of organic sediments, derived oil. LOUISIANA: Belle Isle salt dome, St. Mary Parish; post-Fleming; foraminiferal zonation of Claiborne; Midway. NEW YORK: Thorold sandstone. OKLAHOMA: Migration, Oklahoma City. TEXAS: Variation, migration, Spindletop, Jefferson Co.; post-Fleming; Claiborne.

NO. 6—168 pp. GENERAL: Appalachian gas fields; economic spacing; extraterrestrial hydrocarbons and petroleum genesis; true dip determination. PENNSYLVANIA: Water-flooding, Bradford: "Bradfordian series." VENEZUELA: Andes.

NO 7—152 pp. ARKANSAS: Carbon ratios. CALIFORNIA: Fossil mammal deep well record. COLORADO: Pennsylvanian, Permian, Salt Creek area. GENERAL: Oil and gas securities; bleaching clay; sand compressibility; geophysics and salt domes. KANSAS: Regional investigations; Englevale channel sandstone. OKLAHOMA: Carbon ratios; regional investigations. TEXAS: Permian basin; Hilbig field, Bastrop Co.

NO. 8—164 pp. CALIFORNIA: Oligocene Tumey formation. GENERAL: St. Peter stratigraphy; Vicksburg group; permeability. MICHIGAN: Glacial expression of structure. MISSISSIPPI: Covington Co. OKLAHOMA: Crustal movement, Ouachita Mountains; Talihina formation. TEXAS: Panhandle; Government Wells, Duval Co.; Mercedes field. URUGUAY: Central sedimentary basin. WYOMING: Big Medicine Bow.

NO. 9—152 pp. COLORADO: South Park stratigraphy. GENERAL: Paleozoic crustal movements, Europe and North America. LOUISIANA. Jennings dome overhang, Acadia Parish. MEXICO: Eocene, northeastern. NEW YORK: Thorold sandstone. TEXAS: Brenham dome, Washington and Austin Cos.; New Hardin field, Liberty Co.

NO. 10—164 pp. CANADA: Alberta Foothills structures. GENERAL: Graphic dip. KANSAS: Structure by graphic dip; central uplift. PENNSYLVANIA: Devonian. TEXAS: Fredericksburg group; Bissett formation. UTAH: Southeastern structure.

NO. 11—156 pp. COLORADO: Pennsylvanian Hermosa formation, Gunnison Co. GENERAL: Geology of glauconite. LOUISIANA: Jefferson Island salt dome, Iberia Parish. MISSISSIPPI: Vicksburg group. TEXAS: Dolomite in Permian limestones.

NO. 12—140 pp. BRAZIL: Gondwana sedimentary rocks. CALIFORNIA: Geology. EUROPE: Paleozoic oil? GENERAL: Continental spreading.

1936 VOL. XX.—1684 pp. 12 Nos. Paper. Each .... ($1.00) 1.50

WHOLE VOLUME WITH INDEX: Bound in two parts. Cloth .... ($4.00) 17.00

†**NO. 1**—124 pp. ARKANSAS-OKLAHOMA: Carbon ratios. GENERAL: Petroleum production and supply; shortage, alleviation; structure of domes. MISSISSIPPI: Carboniferous at Jackson. OKLAHOMA: Chattanooga shale, Osage Co. TEXAS: Clay Creek salt dome, Washington Co.

†**NO. 2**—120 pp. CALIFORNIA: Miocene, Palos Verdes Hills; schist-bearing clastics, Venice and Del Rey; Refugian stage, Tertiary. GENERAL: Field photography. LOUISIANA: Côte Blanche salt dome, St. Mary Parish. TEXAS: Hoskins Mound salt dome, Brazoria Co.

†**NO. 3**—140 pp. CALIFORNIA: Organic matter and oil, Santa Fe Springs; bacteria in marine sediments. GENERAL: Rock temperatures; origins of petroleums—chemical and geochemical; continental spreading. OKLAHOMA-ARKANSAS: Correlations by graptolites; Blue-jacket sandstone. TEXAS: Corpus Christi structural basin and salinity.

NO. 4—136 pp. Symposium: MEXICO: Petroleum geology and A.A.P.G.; structure, paleogeography, wells in northeast; micropaleontology, Tampico; geologic road log of Pan-American highway and in Tamaulipas and Nuevo Leon; geology along National Railway. CALIFORNIA: Eocene, Santa Lucia Mountains. OKLAHOMA-ARKANSAS: Ouachita boulders. TEXAS: "Potamides Matsoni" zone (Burkville beds).

NO. 5—156 pp. GENERAL: Stratigraphic, structural accumulation; migration. TEXAS: Orange; cap rock and salt overhang, High Island, Galveston Co.

NO. 6—172 pp. BRAZIL: Gondwana rocks. GENERAL: Marine unconformities; ground water; salt-dome statistics; price of crude; apparent dip; origin of Gulf salt; field photography. OHIO: Source material. TENNESSEE: Mississippian "Ridgetop shale." TEXAS: Conroe; open reservoir, wheat pool, Loving Co.

NO. 7—156 pp. BRAZIL: Gondwana rocks. CALIFORNIA: Discoveries, supply. GENERAL: Tectonic state of earth; geosynclinal boundary faults. OKLAHOMA: Fitts pool, Pontotoc Co.; Cambrian-Ordovician, Arbuckle limestone, Murray Co. PALESTINE:TRANSJORDAN: Bitumen, Dead Sea. TEXAS: East Texas development, Talco field, Titus and Franklin Cos.; Conroe.

NO. 8—156 pp. AUSTRALIA: Northwest Basin. GENERAL: Value of wildcat land; radio transmission. OKLAHOMA: Insoluble residues; Ouachita boulder problem; tectonics, Arbuckle and Ouachita mountains. PENNSYLVANIA: Hebron gas field, Potter Co. TENNESSEE: Upper Paleozoic, Nashville dome. TEXAS: Hardin dome, Liberty Co.

NO. 9—116 pp. BRAZIL-URUGUAY-PARAGUAY: Devonian, Paraná Basin. GENERAL: Foreign literature on petroleum generation. MONTANA: Nye-Bowler lineament, Stillwater and Carbon Cos. NEVADA: Pennsylvanian-Permian. OKLAHOMA: Lower Paleozoic graptolites. TEXAS: Southern Permian Basin. WYOMING: Frontier-Niobrara, Laramie Basin.

NO. 10—112 pp. ARKANSAS-OKLAHOMA: Coal Basin. COLORADO: Dawson and Laramie formations, Denver Basin. MEXICO: Physiographic provinces. SOUTH DAKOTA: Ordovician fossils, Deadwood formation. TEXAS: Recent movements, Balcones fault. TURKEY: Oil in Mürefte?

NO. 11—140 pp. EUROPE: Paleozoic production? GENERAL: Porosity in limestones. GULF COAST: Salt structures. MEXICO: Tampico region. OKLAHOMA: Permian, Pennsylvanian. TRINIDAD: Geology.

NO. 12—156 pp. CALIFORNIA: Structure, southern California.